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CONTENTS.

ORIGINAL ARTICLES.

PAGE

BRYANT, G. E.
Notes on the Genus *Pagria* (Eumolpinae, Coleopt.) (*illustrated*) ... 31

BRYANT, G. E.
New Species of *Podagrica* (Halticinae, Coleoptera) from Africa ... 229

DAVID, W. A. L.
Simple Tests for estimating the Suitability of Mineral Oils as Mosquito Larvicides 195

DAVID, W. A. L.
The Utilisation of Waste Lubricating Oil in Mosquito Larvicides ... 235

EMDEN, F. I. VAN
A Tachinid parasitic on *Plutella maculipennis*, Curt. (*illustrated*) ... 223

GILLETT, J. D.
A Larvascope for Use in Identification of living Culicine Larvae (*illustrated*) 27

HADDOW, A. J.
The Mosquito Fauna and Climate of native Huts at Kisumu, Kenya (*illustrated*) 91

HARRIS, W. V.
Notes on Culicine Mosquitos in Tanganyika Territory (*illustrated*)... 181

HINTON, H. E.
Notes on the Larvae of the three common injurious Species of *Ephestia* (Lepidoptera, Phycitidae) (*illustrated*) 21

HOPKINS, G. H. E.
"Mosquitoes of the Ethiopian Region."—Notes and Corrections (with an Appendix by E. C. C. van Someren) (*illustrated*) ... 175

JONES, M. G.
A Description of *Aphis* (*Doralis*) *rumicis*, L., and Comparison with *Aphis* (*Doralis*) *fabae*, Scop. (*illustrated*) 5

JONES, M. G.
The Summer Hosts of *Aphis fabae*, Scop. 161

CONTENTS.

	PAGE
Leeson, H. S.	
The Occurrence of *Anopheles marteri* in Syria	35
Le Pelley, R. H.	
The Food and Feeding Habits of *Antestia* in Kenya (*illustrated*) ...	71
Le Pelley, R. H.	
A Method of sampling Thrips Populations	147
Lewis, D. J.	
A Method of transporting living Mosquito Larvae (*illustrated*) ...	227
Marshall, Sir G. A. K.	
New injurious Curculionidae (Col.) from the Sudan	1
Mellanby, K., Johnson, C. G., Bartley, W. C. & Brown, P.	
Experiments on the Survival and Behaviour of the Itch Mite, *Sarcoptes scabiei* DeG., var. *hominis*...	267
Perkins, J. F.	
On a new Species of *Ephialtes* (Hym., Ichneumonidae) parasitising the Codling Moth	171
Ramchandra Rao, Y.	
Some Results of Studies on the Desert Locust (*Schistocerca gregaria*, Forsk.) in India	241
Robinson, G. G.	
The relative Toxicity of Rotenone and Pyrethrum in Oil to the Argasid Tick, *Ornithodorus moubata*, Murray (*illustrated*)... ...	273
Saliternik, Z.	
The macroscopic Differentiation of Anopheline Eggs according to their Pattern on the Surface of Water (*illustrated*)...	221
Sellers, W. F.	
The Distribution of the European Spruce Sawfly, *Diprion polytomum* (Htg.) in the Scandinavian and Eastern Baltic Countries (*illustrated*)	149
Tams, W. H. T.	
Note on the Name of the Sugar-cane Borer of Mauritius (Lep., Pyral.)	67
Vinson, J.	
Biological Control of *Diatraea mauriciella*, Wlk., in Mauritius—I. Investigations in Ceylon in 1939 (*illustrated*)	39
Wigglesworth, V. B.	
Some Notes on the Integument of Insects in Relation to the Entry of Contact Insecticides (*illustrated*)	205

CONTENTS.

MISCELLANEOUS.

PAGE

Retirement of Sir Guy Marshall 145

Collections received 69, 143, 219, 283

ERRATA.

Vol. 32, page 315, Table I, first line of figures (*Lasiosina*), last column but one, for " $25(\frac{9}{16})$ " read " $\underline{35(\frac{19}{16})}$ "

,, ,, 319, Table III, second line of averages, third column of figures, for " 6 " read " 4 "

,, ,, 320, line 7, for " uppermost internode " read " uppermost internode but one "

,, ,, 321, line 24, for " 304 " read " 2 ♀♀ and 1 ♂ "

Vol. 33, page 18, lines 20 and 28 and page 161, 10 lines from end, for " *rhoeus* " and " *rhoeum* " read " *rhoeas* "

,, ,, 40, 2 lines from end and page 53, 3 lines from end, for " *supressalis* " read " *suppressalis* "

,, ,, 41, 12 lines from end, for " Badalla " read " Badulla "

,, ,, 43, line 1, for " *Peradenyia* " read " *Peradeniya* "

,, ,, 142, line 9, for " **17** " read " **18** "

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IMPERIAL INSTITUTE OF ENTOMOLOGY.

BULLETIN

OF

ENTOMOLOGICAL RESEARCH.

VOL. 33. 1942.

NEW INJURIOUS CURCULIONIDAE (COL.) FROM THE SUDAN.

By SIR GUY A. K. MARSHALL.

The types of the four new species described below have been deposited in the British Museum (Natural History).

Subfamily ERIRRHININAE.

Smicronyx gossypii, sp. n.

♂♀. Derm black, with uneven brown scaling and variable white spots ; prothorax with a white spot in the middle of the base and a few white scales along the dorsolateral margin ; elytra with variable and irregular white spots ; underside with isolated grey scales, ventrites 3 and 4 with a single transverse row of separated scales across the middle and along the apical margin a row of contiguous scales.

Rostrum a little longer than the head and pronotum, moderately curved, punctato-striate, with rather dense scaling. *Antennae* black, the funicle with broad scale-like white setae. *Prothorax* as long as broad, narrow, only slightly rounded laterally, widest a little behind the middle ; dorsum gently convex longitudinally, with small confluent flattened granules that are mostly concealed by the transverse narrow brown scales. *Elytra* ovate, much broader at the roundly rectangular shoulders than the prothorax and almost parallel from there to the middle, the dorsal outline gently convex, highest at the middle ; the striae very narrow and shallow (except 9 which is very broad and deep), 1–4 almost impunctate, the punctures being distinct in 5–8 ; intervals broad, flat, finely alutaceous ; the narrow scales varying in size, those near the suture mostly narrower than the lateral ones, not entirely concealing the derm. *Legs* black, with separated narrow scales ; front femora with a rudimentary tooth, the others unarmed ; all tibiae with a sharp mucro.

Length 1·6–2·0 mm., breadth 0·7–0·8 mm.

The sexes appear to present no reliable external distinctions.

ANGLO-EGYPTIAN SUDAN : Shambat, 1 ex., on cotton, ix.1926 (*H. W. Bedford*) ; Wad Medani, 2 ex., on cotton, xi.1927 (*H. B. Johnston*), 3 ex., x.1932, 5 ex., v.1933, on cotton (*W. P. L. Cameron*). ERITREA : Dahalak Is., 2 ex., iii.1903 (*Dr. M. Cameron*—type).

Closely allied to *S. kiesenwetteri*, Tourn., from Algeria, which may be distinguished by its red legs and partly red elytra.

Subfamily Tychiinae.

Sibinia vitticollis, sp. n.

♂♀. Derm red-brown, hidden by dense oblong scales above ; scales on head and base of rostrum yellow ; pronotum greyish white with two broad ill-defined yellow stripes ; elytra uniformly greyish white ; underside with dense whiter scales that are shorter and broader than those on the elytra, being almost round in part. The yellow stripes on the pronotum sometimes very pale.

Head with the forehead a little wider than the base of the rostrum and gradually narrowing anteriorly, the transverse impression just behind it feeble. *Rostrum* of ♂ about as long as the pronotum, squamose to a little beyond the middle, the bare apical part flavescent and distinctly punctate ; that of ♀ a little longer and more slender, squamose only to middle, with finer punctures apically. *Antennae* inserted at (♀) or beyond middle (♂) of the rostrum, flavescent, with stiff broad white setae ; funicle gradually widening distally, joint 1 less than half as long as the scape, 2 longer than broad, the rest transverse, 6 rather closely annexed to the club and concealed by the dense white setae. *Prothorax* nearly as long as broad, widest close to the base, only slightly rounded laterally, narrowing rapidly in front, deeply constricted near the apex, which is two-thirds as wide as the base, the basal margin produced in the middle, the projecting scales almost concealing the scutellum. *Elytra* broadly ovate, much wider at the prominent shoulders than the prothorax ; the oblong scales closely contiguous, but not overlapping. *Legs* rather slender, with dense whitish scaling ; tibiae almost straight on the inner edge, the anterior pairs with a minute mucro ; tarsi with joint 3 broader than 2, claws with a basal tooth.

Length 1·8–2·4 mm., breadth 0·7–1·0 mm.

Anglo-Egyptian Sudan : Wad Medani, 1 ♀, on cotton, iii.1920 (*H. H. King*), 3 ♂ 1 ♀, on *Cajanus indicus*, v.1932 (*P. G. Michelmore*), 1 ♀, on clover, v.1932 (*P. G. M.*), 2 ♂ 2 ♀, on cotton, xii.1932, iv.1933 (*W. P. L. Cameron*), 5 ♂, on *Eclipta alba*, v.1933 (*W. P. L. C.*) ; Khartoum, 1 ♀, on *Acacia arabica*, iv.1924 (type), 2 ♂, iii.1928 (*H. B. Johnston*) ; Managil, 1 ♂, on cotton, iii.1925 (*H. B. J.*) ; Kaduru, 1 ♂, on senna, vi.1930 (*J. W. Cowland*).

Allied to *S. sodalis*, Germ., but with rather broader elytra and a narrower subconical prothorax, like that of *bipunctata*, Kirsch, and differing from both by the yellow stripes on the pronotum.

Sibinia brunnula, sp. n.

♂♀. Derm red-brown, with dense pale brown scaling above and greyish white beneath ; pronotum with an indefinite median whitish stripe and becoming whitish laterally ; elytra sometimes with whitish scales among the brown and the deflexed margins whitish ; scutellum white.

Closely allied to but smaller than *S. vitticollis*, sp. n., the description of which applies to it except in the following particulars :—*Head* without any transverse impression behind the forehead. *Prothorax* distinctly less narrowed anteriorly, the scales much shorter and broader, some of them being almost round. *Elytra* with the shoulders somewhat less prominent and the scales slightly broader.

Length 1·5 mm., breadth 0·6 mm.

Anglo-Egyptian Sudan : Khartoum, 1 ♀ on cotton, x.1926 (*H. W. Bedford*) ; Wad Medani, 4 ♀ on cotton, xii.1932, iv.1933 (*W. P. L. Cameron*) ; Khartoum, Sunt Forest, 1 ♂, " common on sunt trees " (*Acacia arabica*), iv.1924 (*H. B. Johnston*—type).

Sibinia sudanica, sp. n.

♂♀. Derm red-brown, concealed by dense scaling which is uniformly pale yellow above (rarely fading to grey) and white beneath.

Head with the forehead a little wider than the base of the rostrum and slightly narrowing anteriorly, with a shallow transverse impression behind it. *Rostrum* as long as the pronotum in ♂, slightly longer in ♀, gradually narrowing from base to apex, moderately curved, densely squamose on the basal half in both sexes, the bare apical half testaceous. *Antennae* inserted at (♀) or a little beyond the middle (♂) of the rostrum, flavescent, with normal narrow white setae ; funicle scarcely widening distally, joint 1 less than half as long as the scape, 2 longer than broad, the rest transverse, 6 not attached to the club. *Prothorax* as long as broad, widest at the base, subconical, rapidly narrowing in front, with the sides very slightly rounded, very shallowly constricted at the apex, which is much narrower than the base (4 : 7), the latter roundly produced in the middle, the scales almost hiding the scutellum ; at the sides and in a broad median stripe the scales are denser than on the rest of the disk. *Scutellum* concolorous. *Elytra* broadly ovate, with prominent humeral calli ; the dense short oblong scales forming regular lines and shortly overlapping at the tips, giving the surface a slightly roughened appearance, especially on the declivity. *Legs* flavous, with dense white scaling ; tibiae almost straight on the inner edge, the anterior pairs with a minute mucro ; tarsi with joint 3 broader than 2, claws with a stout basal tooth.

Length 2·0–2·2 mm., breadth 1·0–1·1 mm.

ANGLO-EGYPTIAN SUDAN : Wad Medani, 1 ♀ on cotton, iii.1920 (*H. H. King*), 1 ♀ on cotton, iv.1933, 1 ♂ on flower of *Cassia fistula*, v.1933, 1 ♀ on cotton, iv.1938 (*W. P. L. Cameron*) ; Shambat, 1 ♂ on cotton, ix.1926 (*H. W. Bedford*) ; Khartoum, 1 ♂ on cotton, x.1926 (*H. W. B.*) ; Shendi, 1 ♂ on *Sorghum*, x.1928 (*A. Hassan*) ; Kadaru, 1 ♂ on senna, vii.1930 (*J. W. Cowland*) ; N. E. Darfur, Taganor, 1 ♀ on *Grewia flavescens*, viii.1930 (*A. P. G. Michelmore*) ; Gash Delta, 3 ♂ 5 ♀ on hambuk (*Abutilon glaucum*), iii.1931 (*H. W. B.*) ; Tendelai, 1 ♂ 1 ♀ bred from " shashut " stem, iii.1932 (*A. M. Makkawi*).

In Desbrochers' key to the palaearctic species of *Sibinia* (Frelon, iv, 1895, p. 100) this species runs down next to *sodalis*, Germ., which differs, apart from coloration, in having the base of the pronotum much less produced, the humeral calli on the elytra less prominent, and the rostrum much longer, parallel-sided and squamose at the base only.

A DESCRIPTION OF *APHIS* (*DORALIS*) *RUMICIS*, L., AND COMPARISON WITH *APHIS* (*DORALIS*) *FABAE*, SCOP.

By Margaret G. Jones, M.A.

Department of Zoology, Cambridge. E.H

Introduction.

Linnaeus (1746) described a black aphis which he found on *Rumex* sp. and called it *Aphis rumicis*. Fabricius (1794) described a black aphis "*Aphis rumicis*," found "in Rumice acuto" and mentioned pale antennae and tibiae. Risso (1826) recorded a species, *Doralis rumicis*, Leach, found in the Mediterranean region, but did not describe it. Koch (1857) recorded *Aphis rumicis*, L., from *Rumex crispus*, feeding chiefly on the stems and flower-stalks. This aphis is also frequently found on thistles and beans. The apterous female has black antennae, white only at the base of the long "fourth joint." The wing-pads and thorax of the alate nymphs are olive-green. Kaltenbach (1874) described black Aphids developing from eggs on dock, and having a second winged generation which settles on beans, thistles, *Chenopodium* sp., and other plants. He observed that the Aphid colonies are on the leaves and flower-stalks. Buckton (1879) gave an illustrated account of a black aphis, *Aphis rumicis*, L., which has a large number of food-plants including *Rumex crispus*, *Carduus lanceolatus*, and broad bean, with furze as its winter host. He noticed the presence of large white flecks on the "pupae."

Börner & Janisch (1922) separated a monophagous dock aphis, which they called *Aphis rumicis*, L. (em. Börner), from the polyphagous *Aphis fabae*, Scop., which has spindle as its winter host, and infests a variety of plants during the summer. They did not, however, describe the dock species fully, although they mentioned the fact that it causes marked leaf-curl.

In his "Aphididae of Great Britain," Theobald (1929) described *Aphis rumicis*, L., as the polyphagous migratory aphis, and gave *Aphis fabae*, Scop., as one of its synonyms. He partly described the apterous and alate viviparous females of a so-called new species, *Aphis davidsoniella*, Theo., which is found on dock. This appears to be identical with Börner's *Aphis rumicis*, L. (em. Börner).

Franssen (1927) agreed with Börner in calling the non-migratory dock aphis *A. rumicis*, L. (em. Börner), and gave some description. He distinguished it from other black Aphids by the number of marginal hairs on the second to fifth abdominal segments being greater than two, and by other characters. In a later paper (1930) he gave some measurements of the alate and apterous viviparous females.

H. Ris Lambers (1934) pointed out that Theobald had failed to distinguish two separate species on dock, which are similar in structure but have a different biology, and prefers Börner's nomenclature.

According to Balachowsky & Mesnil (1936), Newsky (1929) separated a polyphagous *A. rumicis*, L., with long abdominal hairs from an otherwise identical short-haired *A. fabae*, Fab., a view with which they do not agree. They regard all black Aphids as belonging to one species, *A. rumicis*, L., variations being due to habitat, climate, and season.

Börner (1930) reclassified the Aphidoidea, and separated a subgenus *Doralis*, Leach, from the genus *Aphis*, L., taking *Doralis rumicis* (Leach) L., as the type species. Börner & Schilder (1932) gave the characters, based on the chaetotaxy of the new-born nymph, which they use to separate *Doralis* from *Aphis*. They show that the monophagous *Doralis rumicis* differs from the polyphagous *D. fabae* in having apterous males and in causing a marked leaf-curl. Transferences of the former to other host-plants of *D. fabae* always give negative results.

Petherbridge (1939) mentions the occurrence of oviparous females of *Aphis rumicis* on dock which differ from those of *A. fabae* in having few sensoria on an unswollen hind tibia.

The monophagous dock aphis described in this work is considered to be the same as *Doralis rumicis*, L. (em. Börner) and *Aphis davidsoniella*, Theo. The partial descriptions given by Börner and Franssen on the continent and by Theobald in England agree in biology and morphology with the account given below. At present it is impossible to obtain type slides for direct comparison.

Several workers (Davidson 1925, Börner, Franssen, Silvestri 1939) have already given descriptions of the polyphagous *Doralis fabae*, which is of great economic importance. As it is necessary to separate the two species found on dock, the present work is mainly concerned with the morphology and biology of *Doralis rumicis*, compared where necessary with *D. fabae*.

Characters distinguishing the Two Species.

There are several ways by which colonies on *Rumex obtusifolius* can be recognised :—

1. As few as three or four individuals can cause a pipe-like rolling of the leaf towards the midrib, the lower surface being inside (Börner), and this curl is more marked the earlier the growing leaves are attacked. When the leaf is opened out, the largest number of Aphids are found on either side of the midrib, the number decreasing towards the edges, unless the colony is very big, when the lower surface is completely covered. *D. fabae* does not cause this characteristic leaf-curl on dock.

2. The fourth instars of the alatae have no white markings on the abdomen so noticeable in *D. fabae* (fig. 7).

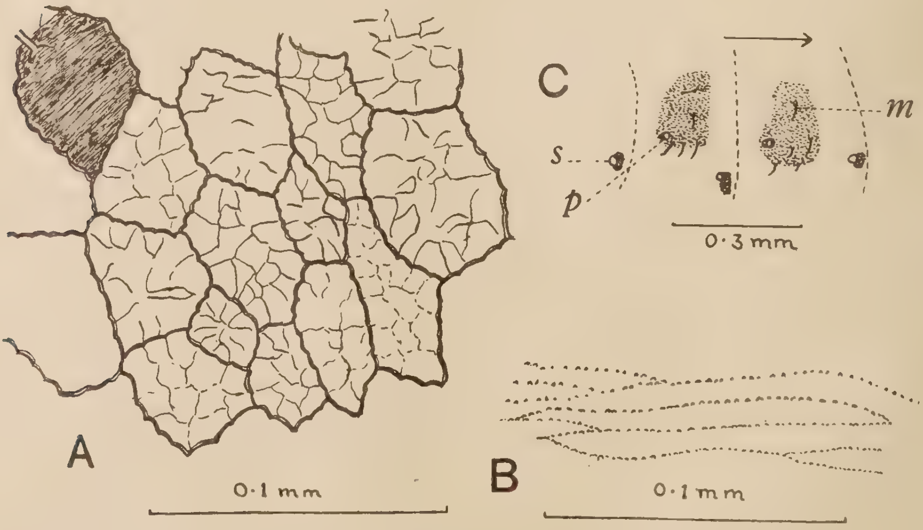

Fig. 1. *D. rumicis*, L. : A, reticulations on the body surface of the abdomen ; B, reticulations on the last two abdominal segments ; C, lateral view of abd. segs. 2 and 3 : *m*, marginal hair ; *p*, papilla ; *s*, spiracle.

3. When single adults are examined : (i) The antennae of the apterous viviparous and oviparous females are found to be dark in colour, except for the base of the third joint which is sometimes lighter than the more distal part (Koch), contrasting with the third, fourth, and part of the fifth joints of *D. fabae,* which are white (fig. 3). (ii) The number of marginal hairs on the second abdominal segment is always at least four, and on the following two segments there are four or more (Franssen) (figs. 1, 2), while *D. fabae* has only two such hairs on the second abdominal segment, and never more than three on the following segments. (iii) The surface of the body has a characteristic reticulation, especially visible in the abdominal region. If individuals are treated with a 50 : 50 mixture of 70 per cent. alcohol and 70 per cent. lactic, cleared in 75–95 per cent. phenol and mounted in Berlese's fluid, this reticulation is very distinct (fig. 1). The mesh of this network becomes closer on the last three segments and on the thorax of the alatae (fig. 1, B).

Description and Comparison of the different Generations.

The apterous viviparous females are described fully, and the remaining forms chiefly by diagrams so as to avoid needless repetition of common characters.

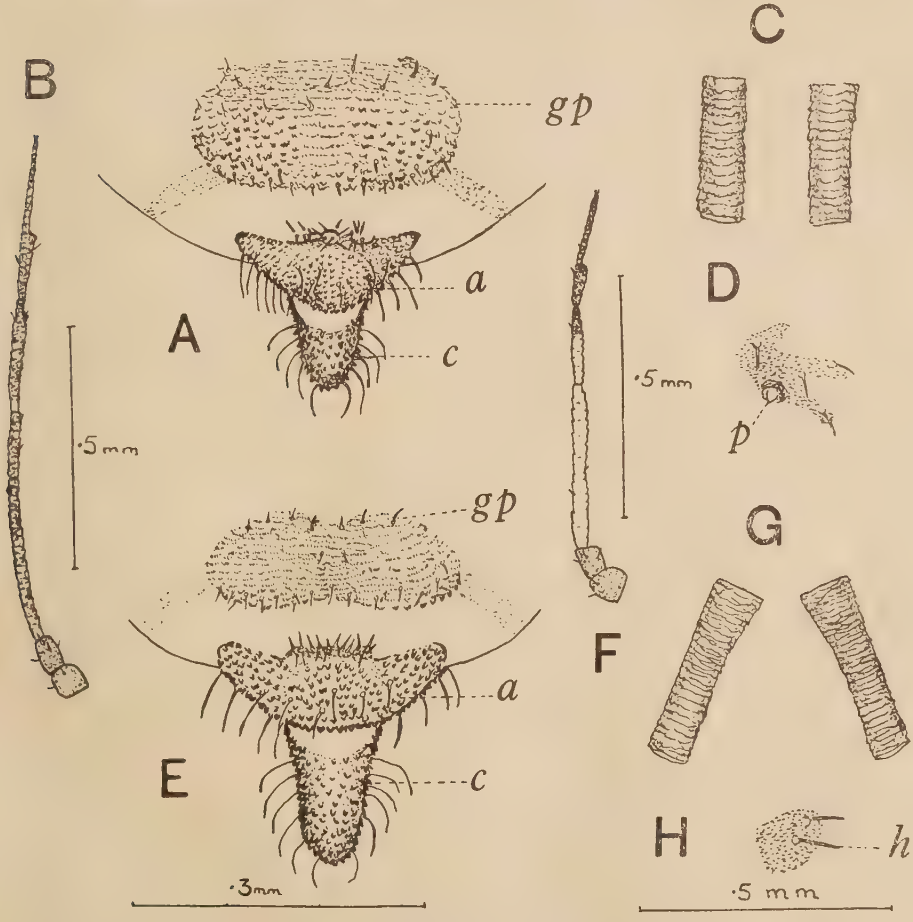

Fig. 2. Fundatrices, A–D of *D. rumicis,* L., E–H of *D. fabae,* Scop. ; A, E, ventral surface of posterior end of abdomen ; B, F, antenna ; C, G, cornicles ; D, H, marginal area of second abd. seg. : *a,* anal plate ; *c,* cauda ; *gp,* genital plate ; *h,* marginal hair ; *p,* papilla.

Important points are, however, mentioned under the appropriate headings. At the end of each section, except the sexuparae and males, is a table of comparison with *D. fabae.* Because of the variations in body size due to feeding and viviparity, the length of the hind tibia is taken as a measure of the size of the individual in all the tables. This may not be a good measure for the oviparous female of *D. fabae,* but it seems to be the most generally useful.

Fundatrices (fig. 2).

The fundatrices are apterous and the antennae are six-jointed or incompletely six-jointed, and bear few hairs (fig. 2, B). The pro-, meso-, and metathoracic segments bear lateral papillae, and occasionally these are double. Dark markings are usually visible on the dorsal surfaces of abdominal segments 1–5, and always on 6, but the pattern is not so full as that of the apterous viviparous female. Dark marginal areas are present, and papillae are often found on abdominal segments 2–5 (fig. 2, D). The cornicles and cauda are shorter than those of the later apterous forms, while the markings of the legs are very similar (fig. 2).

TABLE I.

Comparison of the fundatrices of D. fabae *and* D. rumicis.

Character	*D. fabae*	*D. rumicis*
Host-plant	*Euonymus europaeus* *Viburnum opulus*	*Rumex obtusifolius*
Body length	2·4 mm.	2·2 mm.
S.E. ±	0·079 mm.	0·059 mm.
Length of hind tibia	0·818 mm.	0·87 mm.
S.E. ±	0·0098 mm.	0·0098 mm.
Length of cornicles	0·184 mm.	0·177 mm.
S.E. ±	0·00096 mm.	0·002 mm.
Antenna	5-jointed, tips and base dark	5–6 jointed, all dark
Antennal joints 3 & 4, undivided	0·37 mm.	0·49 mm.
S.E. ±	0·0035 mm.	0·013 mm.
Joints 3 & 4, separate	No definite division under low power of microscope	0·346 : 0·197 mm.
S.E. ±	...	0·0051 : 0·007 mm.
Joints 5 & 6	0·155 : 0·23 mm.	0·22 : 0·3 mm.
S.E. ±	0·0018 : 0·003 mm.	0·0032 : 0·0024 mm.
Dorsal abdominal pattern	Occasional and faint	Usually present
Thoracic papillae	Prothorax	Pro-, meso- and metathorax
Abdominal papillae	Occasional	Variable, often complete

The arithmetic means are based on measurements of 28 individuals.

Apterae viviparae (fig. 3).

The apterae are black or greenish black in colour. The head-capsule and antennae, with the occasional exception of the third joint, are darkly pigmented, and the rostrum reaches to the base of the second coxa. There are dark markings on the terga of the meso- and metathorax and of the abdominal segments (fig. 3, D) ; the size and shape of these bands vary slightly according to conditions, being smaller in an individual from a crowded colony, and towards the end of the summer. There are

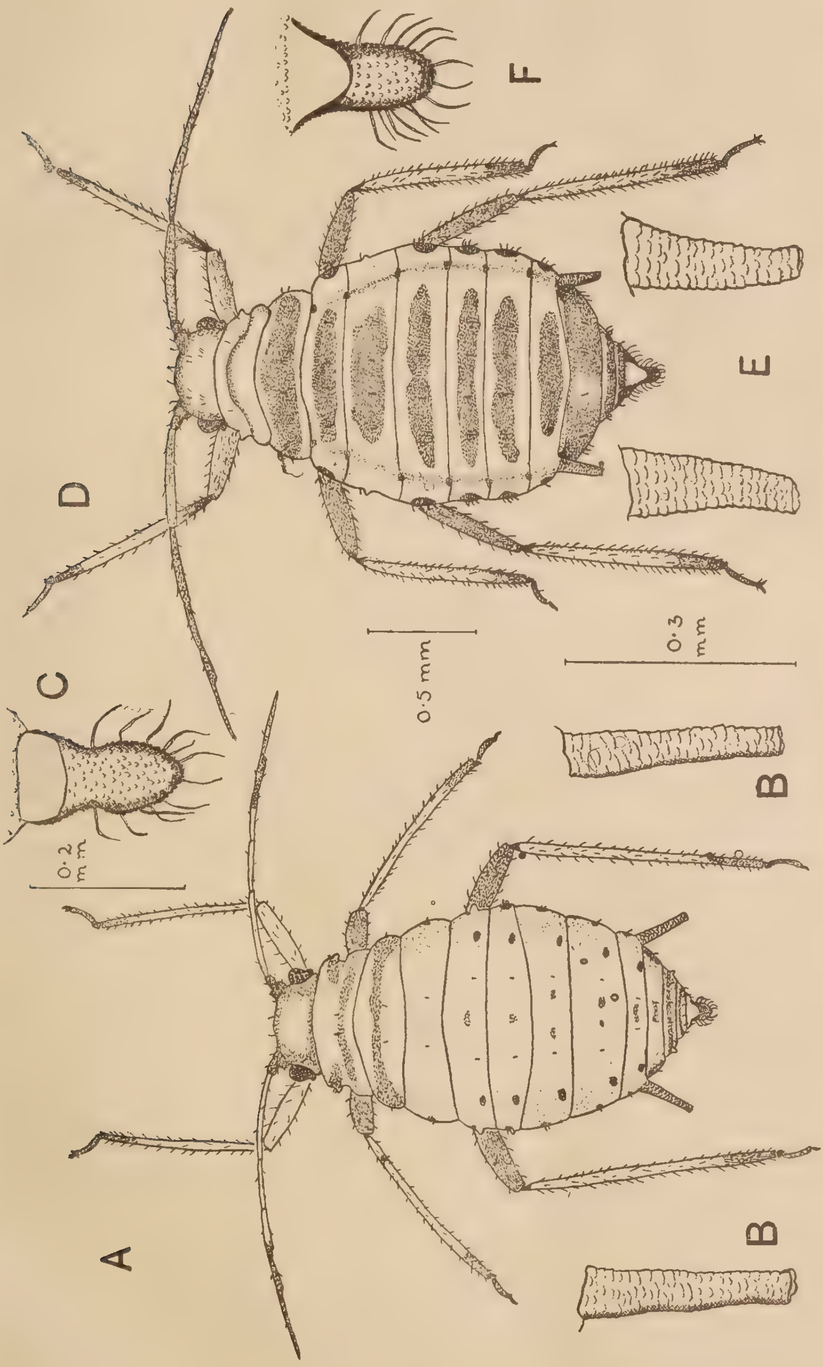

Fig. 3. Apterae viviparae, A–C of *D. fabae*, D–F of *D. rumicis*: A, D, dorsal view, B, E, cornicles; C, F, cauda.

also dark marginal areas on the metathorax, and on abdominal segments 2–5, and from these areas arise the 4 or 5 marginal hairs. The distal regions of the tibia and tarsus of the three pairs of legs are dark, while the femora of the second and third pairs are similarly deeply pigmented. The cornicles are black and tend to be relatively shorter and stouter than those of *D. fabae* (fig. 3, B, E). Papillae are present on the prothorax, and on abdominal segments 1 and 7, and generally on some of the intervening segments ; a specimen with a full complement of papillae is sometimes found, more frequently in the generations of the early summer. The wax-glands are found in a groove, which tends to separate off a margin from the median region of the body. Usually four rows of dorsal hairs can be distinguished. Ventrally there are two rows of stiff hairs on each of the first seven abdominal segments, and the square genital plate bears many hairs, as do the anal plate and cauda (fig. 3, C, F ; 2, A). The spiracles are anterior and slightly ventral to the marginal areas (fig. 1, C).

TABLE II.

Comparison of the Apterae viviparae of D. rumicis *and* D. fabae.

Character	*D. fabae*	*D. rumicis*
Hind tibia ... ... S.E. ±	1·107 mm. 0·0109 mm.	1·104 mm. 0·015 mm.
Cornicles ... ... S.E. ±	0·324 mm. 0·0043 mm.	0·277 mm. 0·0028 mm.
Antenna	3rd and 4th joints white	Black, or light patch at base of 3rd joint
Antennal joints 3 & 4 ... ... S.E. ±	0·38 : 0·2625 mm. 0·0041 : 0·0039 mm.	0·405 : 0·29 mm. 0·0033 : 0·0039 mm.
Joints 5 & 6 ... ... S.E. ±	0·234 : 0·475 mm. 0·0032 : 0·0045 mm.	0·254 : 0·42 mm. 0·0028 mm. : 0·0026 mm.
Length of hairs on antennal joints 3 & 4 ... ... S.E. ±	28·5 μ 0·95 μ	28·5 μ 0·336 μ
*Rhinarium hair ... ... S.E. ±	22·54 μ 0·67 μ	26·51 μ 0·607 μ
Marginal hairs on abdominal segments 2–5 ... ... S.E. ±	52·25 μ 1·14 μ	40·21 μ 1·02 μ
Dorsal body markings	Small or absent	Present
White bands on abdomen (wax)	Often present	Absent

* Hair nearest the primary rhinarium (sensorium) on the fifth joint of the antenna (Franssen 1930).

The arithmetic means are based on measurements from more than 60 individuals, from different colonies, on *Rumex obtusifolius* (both species), *R. hydrolapathum* (*D. rumicis*), *Beta vulgaris*, *Solanum nigrum*, *S. crispum* and *Cirsium arvensis* (*D. fabae*).

Alatae viviparae (fig. 4).

The alatae are more strongly chitinised than the apterae, especially in the head and thorax. The antennae are darkly pigmented, and sensoria are present on the third joint and occasionally on the fourth. On the abdominal terga are dark bands which extend to the wax-glands in the first five abdominal segments. The band on the sixth tergum is particularly well defined, and is often fused with the dark marginal area which surrounds the posterior border of the cornicles (fig. 4, I). The cornicles are shorter than those of the apterae, and there is no semi-circular, unpigmented

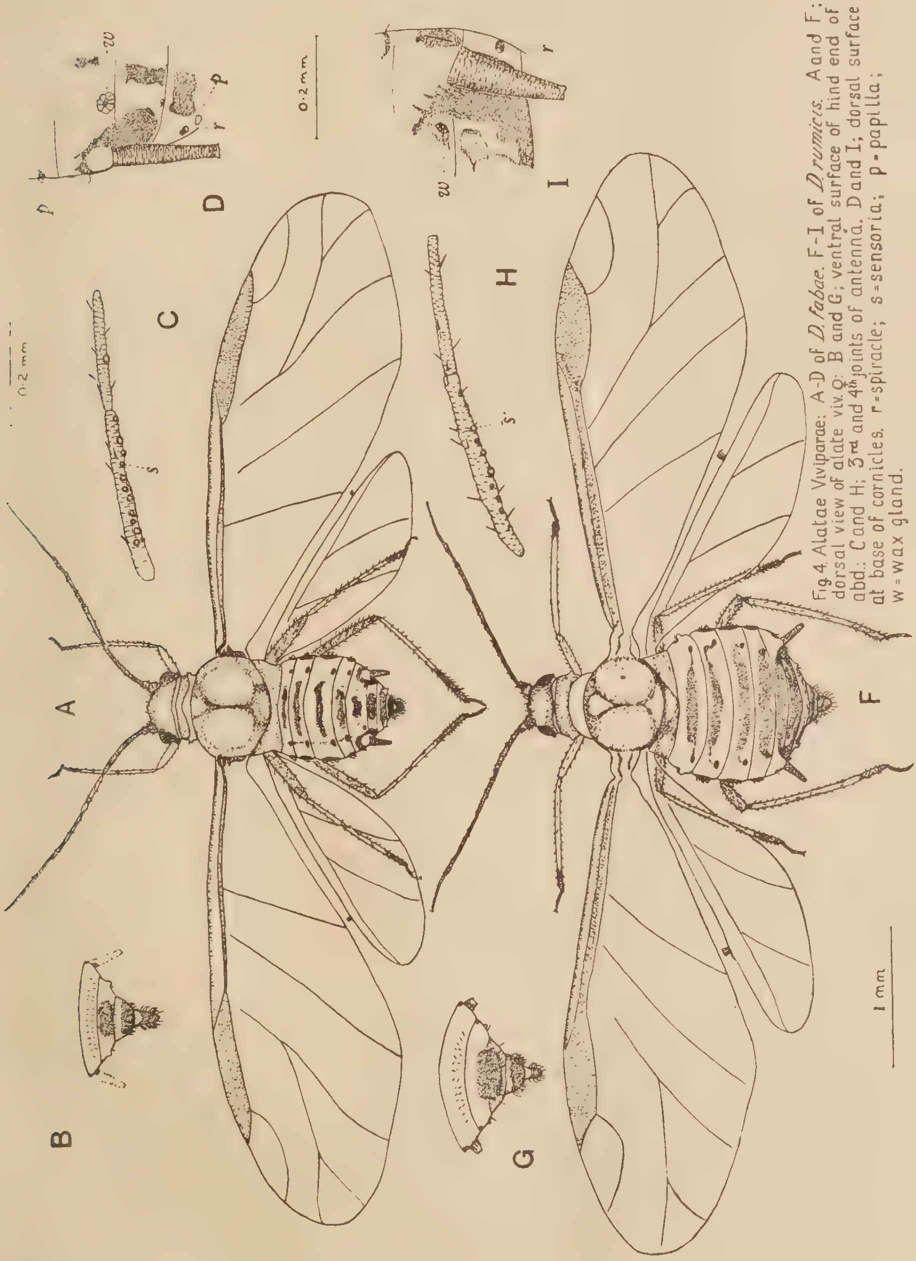

Fig. 4. Alatae Viviparae: A-D of *D. fabae*. F-I of *D. rumicis*. A and F; dorsal view of alate viv. ♀: B and G; ventral surface of hind end of abd.: C and H; 3rd and 4th joints of antenna. D and I; dorsal surface at base of cornicles. r = spiracle; s = sensoria; p - papilla; w = wax gland.

region at the anterior border, as in *D. fabae* (fig. 4, I, D). The occurrence of papillae on abdominal segments 2–5 is variable. There are 5 (S.E. ±0·022) hooks attaching the hind wing to the fore.

Small alatae arising from a crowded colony or on a poor host-plant may show some reduction in the size of the dorsal bands, but the dark marginal areas bearing the hairs are always present.

TABLE III.

Comparison of the Alatae viviparae of D. rumicis *and* D. fabae.

Character	*D. fabae*	*D. rumicis*
Hind tibia	1·126 mm.	1·15 mm.
S.E. ±	0·0102 mm	0·014 mm.
Cornicles	0·248 mm.	0·224 mm.
S.E. ±	0·0033 mm.	0·0025 mm.
Antennal joints 3 & 4	0·35 : 0·263 mm.	0·396 : 0·31 mm.
S.E. ±	0·0027 : 0·0025 mm.	0·0039 : 0·0038 mm.
Joints 5 & 6	0·235 : 0·491 mm.	0·268 : 0·447 mm.
S.E. ±	0·0022 : 0·0036 mm.	0·0029 : 0·0037 mm.
Length of hairs on antennal joints 3 & 4	27·97 μ	27·63 μ
S.E. ±	0·448 μ	0·867 μ
Marginal hairs on abdominal segments 2–5	55·11 μ	41·08 μ
S.E. ±	0·86 μ	1·51 μ
Dorsal body markings	Short bands; light semi-circular area at base of cornicle	Long bands; no light semi-circular area at base of cornicles
Hooks on hind wing	3	5
S.E. ±	0·14	0·022
Sensoria on antennal joint 3	15	10
S.E. ±	0·27	0·17

The arithmetic means are based on measurements from more than 60 individuals, from different colonies on the same host-plants as in Table II.

Sexuparae.

The females which produce the sexual forms are apterous and differ little from the summer forms, except that they are slightly smaller. The dorsal abdominal markings are less distinct and may be reduced to black spots at the bases of the dorsal hairs. One or two pseudosensoria are sometimes found on the hind tibiae. There is no distinct gynoparous form; the same female is capable of producing apterae, males and oviparous females, and thus differs markedly from the alate migratory gynopara of *D. fabae*, and corresponds more with the apterous viviparous female which produces gynoparae, males and apterae viviparae, on the summer host-plant.

TABLE IV.

Measurements of the Sexuparae of D. rumicis.

	Hind tibia	Cornicles	Antennal joints			
			3	4	5	6
Mean ∴	1·03	0·261	0·38	0·278	0·25	0·405 mm.
S.E. ±	0·0202	0·00475	0·0062	0·0054	0·0031	0·0027 mm.

The above figures are based on measurements from 23 individuals on *Rumex obtusifolius*.

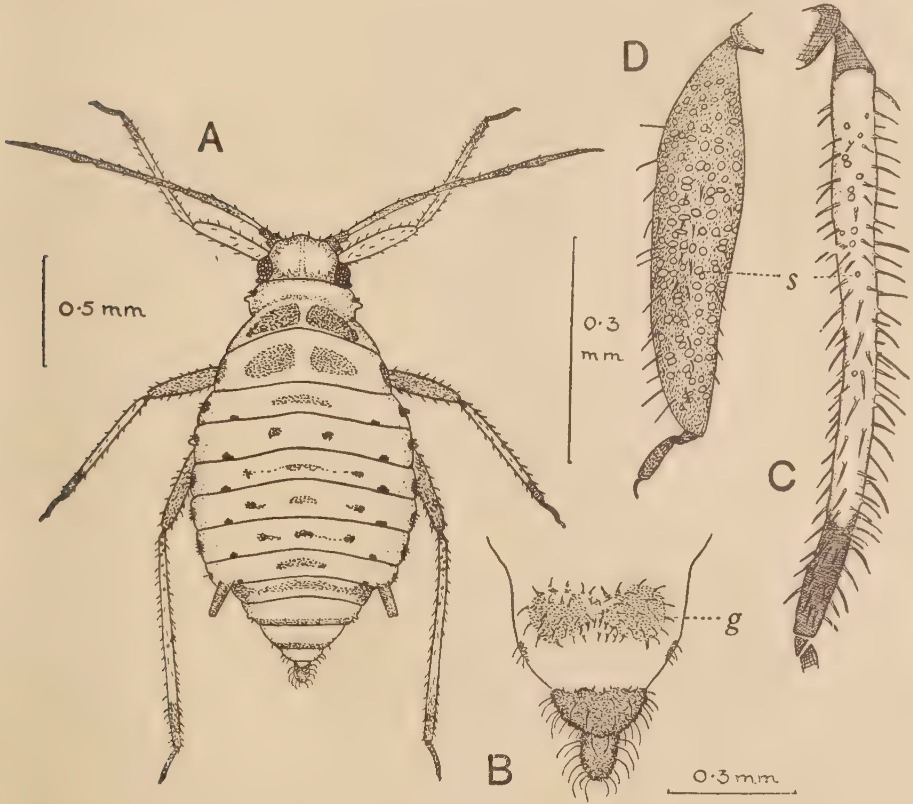

Fig. 5. Oviparae, A–C of *D. rumicis* : A, dorsal view ; B, ventral view to show bifid genital plate ; C, hind tibia ; *g*, genital plate ; *s*, sensoria ; D, hind tibia of *D. fabae*.

Oviparae (fig. 5).

The oviparae can be distinguished from the apterae viviparae by the greater elongation of the posterior end of the abdomen behind the cornicles. The body is smaller than that of the apterae viviparae, and the dark markings on the abdominal terga are much reduced, but the dark marginal areas bearing the hairs are always present. The genital plate is bifid, and the hind tibiae bear a small number of pseudosensoria, but they are not swollen as in *D. fabae* (fig. 5, B, C, D (Petherbridge)).

TABLE V.

Comparison of the Oviparae of D. rumicis *and* D. fabae.

Character	*D. fabae*	*D. rumicis*
Host-plant	*Euonymus* sp., *europaeus* type *Viburnum opulus*	*Rumex obtusifolius* *R. hydrolapathum*
Hind tibia	Swollen and shortened	Not swollen
Length of hind tibia	0·577 mm.	0·871 mm.
S.E. ±	0·0079 mm.	0·0056 mm.
Pseudosensoria on hind tibia	> 100	17
S.E. ±	... ...	0·542
Cornicles	0·124 mm.	0·217 mm.
S.E. ±	0·0009 mm.	0·002 mm.
Antenna	5–6 jointed, tips and base dark	6 jointed, all dark
Antennal joints 3 & 4	0·169 : 0·126 mm.	0·308 : 0·221 mm.
S.E. ±	0·0033 : 0·0023 mm.	0·0023 : 0·0019 mm.
Joints 5 & 6	0·1415 : 0·298 mm.	0·212 : 0·37 mm.
S.E. ±	0·0021 : 0·0031 mm.	0·0016 : 0·0023 mm.
Joints 3 & 4 undivided	0·269 mm.	None
S.E. ±	0·004 mm.	
Dorsal body markings	None	Small
Dark marginal areas	Small or absent	Present

The arithmetic means are based on measurements from more than 60 individuals from different colonies.

Males (fig. 6).

The males are apterous and smaller than any of the other generations ; this difference of size lies mainly in the thorax and abdomen. They are darkly pigmented, and the antennae bear a large number of secondary sensoria on joints 3, 4 and 5. The dorsal pattern of the thorax, abdomen and marginal areas, is well marked. The external genitalia are clearly visible on the ventral surface, and consist of two parameres with a median aedeagus, chitinised proximally (fig. 6, C, D). Papillae are very rarely present, but there may be 1 to 3 pseudosensoria on the hind tibia.

TABLE VI.

Measurements of the Males of D. rumicis.

(As the males of *D. fabae* are alate, comparison is unnecessary.)

	Hind tibia	Cornicles	Antennal joints				Sensoria		
			3	4	5	6	3	4	5
	mm.	mm.	mm.	mm.	mm.	mm.			
Mean	0·709	0·132	0·272	0·218	0·186	0·328	17	14	9
S.E. ±	0·0055	0·001	0·002	0·002	0·0012	0·002	0·323	0·30	0·162

The arithmetic means are based on measurements of 60 individuals from different colonies on *Rumex obtusifolius*.

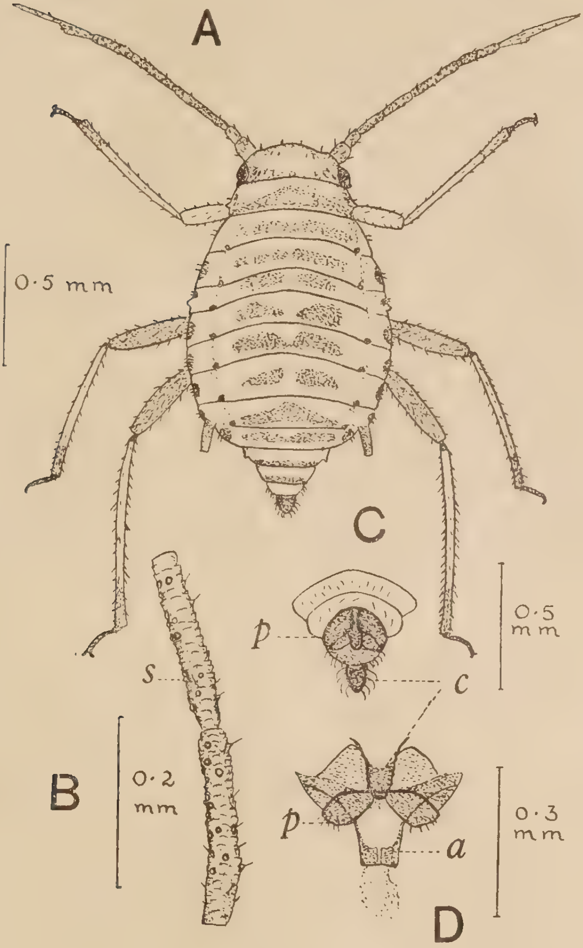

Fig. 6. Male of *D. rumicis*: A, dorsal view; B, 3rd and 4th joints of antenna; C, external genitalia; D, same with aedeagus extended; *a*, aedeagus; *c*, cauda; *p*, paramere; *s*, sensoria.

Eggs.

When the eggs are laid, they are orange-brown in colour, but change to a shining black in a few days, and pass through the winter in this stage. They are oval in shape, and laid in large numbers among the old leaf-bases.

TABLE VII.

Comparison of the Eggs of D. rumicis *and* D. fabae.

	D. fabae	*D. rumicis*
Length	0·551 mm.	0·689 mm.
S.E. ±	0·0037 mm.	0·0032 mm.
Width	0·245 mm.	0·285 mm.
S.E. ±	0·002 mm.	0·0021 mm.

Nymphs of the apterous and alate viviparous females.

During its development, the dock aphis passes through four instars before becoming adult, the actual length of each instar varying according to external conditions.

The first instar is about 0·9 mm. long, and pale in colour. The antennae are four-jointed and the tip of the last joint is dark. When at rest, the rostrum reaches beyond the base of the third coxae, and the labrum almost to the first coxae. At the side of each abdominal segment there is a single marginal hair. On the dorsal surface of the body are two longitudinal rows of hairs on either side of the middle line, one pair to each segment of the thorax and abdomen. Similarly, there are two rows of hairs on the ventral surface of the abdomen, and the genital and anal plates both bear four hairs (Börner 1932).

The second instar is about 1·1 mm. long, and darker in colour. The antenna is 5-jointed, and the rostrum reaches half-way between the second and third coxae. On the abdominal segments 2–4 and 6 are two marginal hairs.

By the third instar, the length of the apterous nymph has increased to approximately 1·34 mm., and although the antennae are normally 5-jointed, the third joint is often imperfectly divided into two. The distal antennal joint is dark, and the cornicles are longer than those of the second stage.

The fourth instar is black, and about 1·76 mm. long. The antennae are completely 6-jointed, and dark in colour. The characteristic reticulations of the body surface

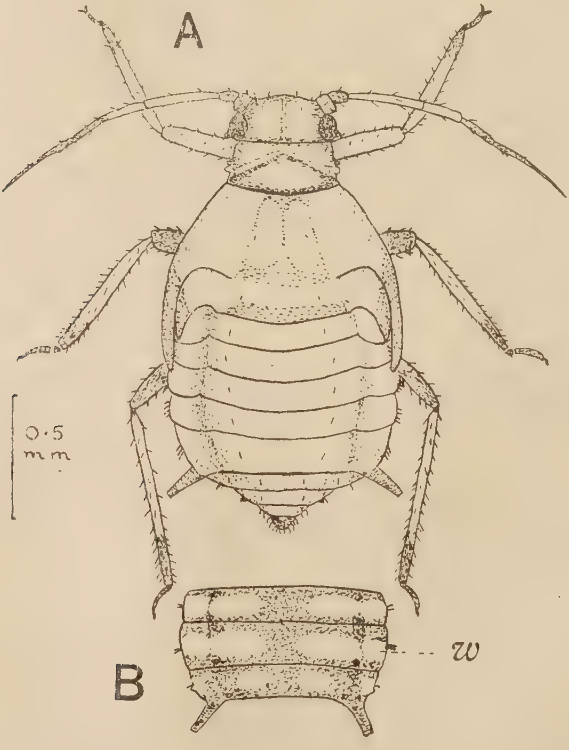

Fig. 7. Fourth instar alate nymph : A, *D. rumicis* ; B, abdominal segments 3–5 of *D. fabae*, dorsal view ; *w*, white wax bands.

are pronounced. The rostrum reaches to the second coxae and the marginal hairs have increased to four. Papillae may be present on the margins of the abdomen. The cauda is still rounded, a character which enables this stage to be separated easily from the adult with the naked eye. The cornicles are longer than those of the previous stage.

The nymphs of the alatae show the development of wing-pads in the third instar. These pads, on the sides of the meso- and meta-thorax are olive-green in colour. The antennae are incompletely 6-jointed, and this stage appears to be slightly larger than the corresponding stage of the apterae (length approx. 1·42 mm.).

In the fourth instar, the wing-pads are longer, and the position of the developing wing muscles in the thorax is visible. The length is variable (1·52–2·05 mm.), and the white patches on the abdomen, which are so distinct on the dorsal surface of *D. fabae,* are absent (Buckton, 1879) (fig. 7).

Biology.

The dock aphis has a wide distribution, and has been recorded from Wales, central England and East Anglia. A heavy attack can kill the leaves and stem of the host-plant, but usually, when the infestation of any one plant is heavy, the apterous females migrate to surrounding plants in great numbers, remaining only on *Rumex obtusifolius* and *R. hydrolapathum*, where leaf-curl is rapidly induced. Continental workers record infestations of the dock aphis on *Rumex maritimus*. The alatae, which arise in large numbers during the summer months (May–August), also serve to disperse the species and to find new docks. In normal years, for example 1939, 1940, and 1941, the dock aphis was more common on dock than the bean aphis.

The eggs hatch out in April, the date depending on the weather. The young fundatrices are found only on the inner leaves of *Rumex obtusifolius*. They take about three weeks to mature, and produce mainly apterous young, but a number of alate forms may arise. These fundatragineae do not appear to differ from the succeeding summer generations.

During the summer, rapid parthenogenetic reproduction takes place, and the species is widely dispersed by both the alatae and the apterae.

Host Transference Experiments.

Although this aphis is normally found on dock, several transferences were tried ; the results (Table VIII) show that colonies are established only on species of *Rumex*.

TABLE VIII.

The Results of Host Transference Experiments.

Original host-plant	Trial host	Number of trials	Result
Rumex obtusifolius ...	*Euonymus europaeus*	6	No colony established
	Beta vulgaris	8	No colony established
	Vicia faba	6	No colony established
	Viburnum opulus	4	No colony established
	Rumex obtusifolius	Many	Colonies always established
Rumex hydrolapathum	*Beta vulgaris*	1	No colony established
	Vicia faba	1	No colony established
	Rumex obtusifolius	1	Colony established

In each trial a few apterous or alate viviparous females were placed on a clean host-plant and enclosed under an inverted lamp-glass with a muslin top. The plants were kept small.

Cage Experiments.

The results from these transferences were confirmed by further experiments under more natural conditions, where Aphids were given a choice of several host-plants, enclosed under a large muslin cage.

Three cages were set up in the following way :—

Single roots of known host-plants of *D. fabae* were planted around a central dock plant in a circle of about 2 foot radius, and when these plants were established, the central dock plant was infested with *D. rumicis*, and the whole enclosed by a muslin cage. These cages consisted of a 3-yard length of muslin, held in position by five 4 ft. stakes, so arranged that the height of the cages was 3 ft. When the colony was established, the cages were roofed over with muslin, and the plants were examined approximately every four days, and kept small so that they did not touch one another.

Results. Plots A and B.

A. July 3rd–28th. B. July 14th–Aug. 4th.

Central plant. *Rumex obtusifolius.*

Surrounding plants. *Vicia faba, Beta vulgaris, Cirsium arvensis, Euonymus europaeus, Papaver rhoeus, Chenopodium album.*

Although the central plant became overcrowded and eventually died, there was no infestation of any of the other plants. Apterae migrated over the surrounding plants, but did not produce colonies, while alatae tended to congregate on the roof and sides of the cages and did not produce any offspring on the surrounding plants.

Plot C.

Central plant. *Rumex obtusifolius.*

Surrounding plants. *Arctium lappa, Vicia faba, Beta vulgaris, Rumex obtusifolius, Papaver rhoeum, Cirsium arvensis.*

Here the original infestation was a natural one. After a week, the second dock was also infested and alatae were present. As the numbers of Aphids increased, many walked over the sides of the cages and on the plants. On two occasions apterae were found feeding on bean and beet, but no colonies were produced, and after three weeks both docks were nearly dead, and very few living Aphids could be found inside the cage.

These results show that, among the given plants, *D. rumicis* infests only *Rumex obtusifolius.*

Olfactometer Experiments.

The responses of the alatae were further tested in the laboratory, using an olfactometer, a slightly modified version of that used by Thorpe & Jones (1937) and

TABLE IX.

The Responses of D. rumicis *and* D. fabae *to Dock Odour.*

(S.E. = $\frac{pq}{n}$ when $p=0{\cdot}5$ and $q=1-0{\cdot}5$. n=total number of Aphids.)

	Number of trials	Dock	Blank	Total	S.E.	χ^2	P
O. rumicis...	8	828 55·7%	658 44·3%	1,486	1·3%	11·499	0·10–0·20
D. fabae ...	4	82 48·5%	87 51·5%	169	3·8%	0·89	0·90–0·95

Thorpe (1938). The experiments were carried out at a temperature of 25°C. and at a humidity of 70 per cent. Alatae were given a choice of the odour of dock and air. The dock odour was produced by drawing a current of air over the leaves and flowers of *Rumex obtusifolius,* contained in a small bottle. The air stream was passed through a similar bottle, containing a little water. A similar experiment using the alatae of *D. fabae* was also carried out, and the results are compared in Table IX.

The observed distribution of *D. rumicis* was significantly different from that to be expected by chance, *i.e.* 50–50 per cent. distribution, but the attraction was not very great. The responses of *D. fabae* corresponded to a chance distribution. The homogeneity of the two series of observations about their own mean (tested by calculating the value of χ^2) was satisfactory.

Origin of Sexual Forms.

Towards the end of September the production of alatae ceases, and early in October the sexuparae arise. The early ones produce a mixture of oviparae, males and more apterae, but the later ones produce chiefly males and oviparous females. The number of males produced is small compared with the number of oviparae, as can be seen from Table X, which records the total progeny from 28 sexuparae.

TABLE X.

The Progeny of Sexuparae.

Number sexuparae mothers	Apterae viviparae (sexuparae ?)	Males	Oviparae	Nymphs	Total
28	4	42	358	39	443

The males are very active, searching for the young oviparous females and conjugating with them. The oviparae walk to the base of the plant, where they lay their eggs on the leaf-bases and on other small plants near the host. By the end of October very few living Aphids are to be found.

Summary.

1. A review of the early literature on the occurrence of black Aphids on dock shows that confusion has arisen between two distinct species, the polyphagous bean-spindle aphis and the monophagous dock aphis. A discussion on the nomenclature of the two species follows and the names *Aphis* (*Doralis*) *fabae*, Scop., and *Aphis* (*Doralis*) *rumicis*, Linn., used on the continent, are adopted.

2. The different generations are described and figured. A comparison of *D. rumicis* and *D. fabae* shows that both colonies and single individuals can be distinguished easily from one another.

3. The results of host transference experiments show that *D. rumicis* only colonises plants belonging to the genus *Rumex*, and the alatae viviparae show some slight response to the odour of dock.

4. There is no gynopara as in *D. fabae*, and the sexupara gives rise to apterae viviparae, males and oviparae.

Acknowledgments.

I wish to thank Mr. F. G. W. Jones of the School of Agriculture, Cambridge, for suggesting the line of work and allowing me to use his slides and some of his records, and Dr. A. D. Imms for his help and criticism.

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NOTES ON THE LARVAE OF THE THREE COMMON INJURIOUS SPECIES OF *EPHESTIA* (LEPIDOPTERA, PHYCITIDAE).

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(Plate I.)

The larvae of the three common species of *Ephestia*, *E. kühniella*, Zell., *E. elutella*, Hb., and *E. cautella*, Wlk., are serious pests of stored food products, particularly cereals, dried fruits, nuts, and cacao. These species often occur together on stored foods, *e.g.*, *E. elutella* and *E. cautella* on dried fruit, or *E. kühniella* and *E. elutella* on grain. Sometimes all three are found together on the same product. To know what species are present is of considerable importance, since they differ in the amount of damage they are likely to do, in their resistance to fumigants, in the frequency with which they are recorded as pests of other products, etc. It has not hitherto been possible to identify the larvae with certainty except by breeding them out, which is unsatisfactory, both because of the time it takes and because it frequently happens that many of the larvae confined in breeding cages die of " wilt."

It was found that by comparing the diameter of the eighth abdominal spiracle with the diameter of the enclosed membranous area around the base of seta rho (ρ) it is possible to distinguish the mature or nearly mature larvae of *E. elutella* from both *E. cautella* and *E. kühniella*, and by comparing the relative distance of epsilon (ε) from the same spiracle it is possible to distinguish with certainty all stages of *E. cautella* from both *E. kühniella* and *E. elutella*. By using these characters mature larvae of the three species may easily be distinguished with only the aid of a hand lens (mag. ×15). To distinguish earlier instars it is, of course, necessary to use a microscope. In the keys given below, *Plodia interpunctella*, Hb., is included, as it is frequently found in the same foods as *Ephestia* and is also frequently confused with the latter.

The drawings were made by me with the aid of a camera lucida, and the lines next to them correspond to a length of 0·20 mm. unless otherwise indicated. The names of the setae are those given by Fracker (1915).

I have to thank Professor J. W. Munro and Dr. O. W. Richards for suggesting this work and supplying the necessary larvae, Mr. N. D. Riley for his interest and encouragement in the preparation of this paper, and Mr. W. H. T. Tams for his kindness in allowing me to publish his excellent photographs of *Ephestia*.

*Key to Mature or nearly Mature Larvae.**

1. First eight abdominal segments with only seta rho of eighth segment (fig. 1), arising from a sclerotised plate. Ninth abdominal segment with alpha, beta, and rho not arising from sclerotised plates..................*Plodia interpunctella*, Hb.
   First nine abdominal segments with all dorsal setae (except sometimes epsilon) arising from sclerotised plates (Pl. I, figs. 1, 2)..2
2. Eighth abdominal segment with spiracle not more than two-thirds as broad as membranous part enclosed by sclerite of seta rho (fig. 5). Prothorax with diameter of spiracle much less than distance between Kappa setae (fig. 6)...*Ephestia elutella*, Hb.

   Eighth abdominal segment with spiracle as broad as or broader than membranous part enclosed by sclerite of seta rho (figs. 3, 4). Prothorax with diameter of spiracle as great as or greater than distance between Kappa setae (fig. 7).........3

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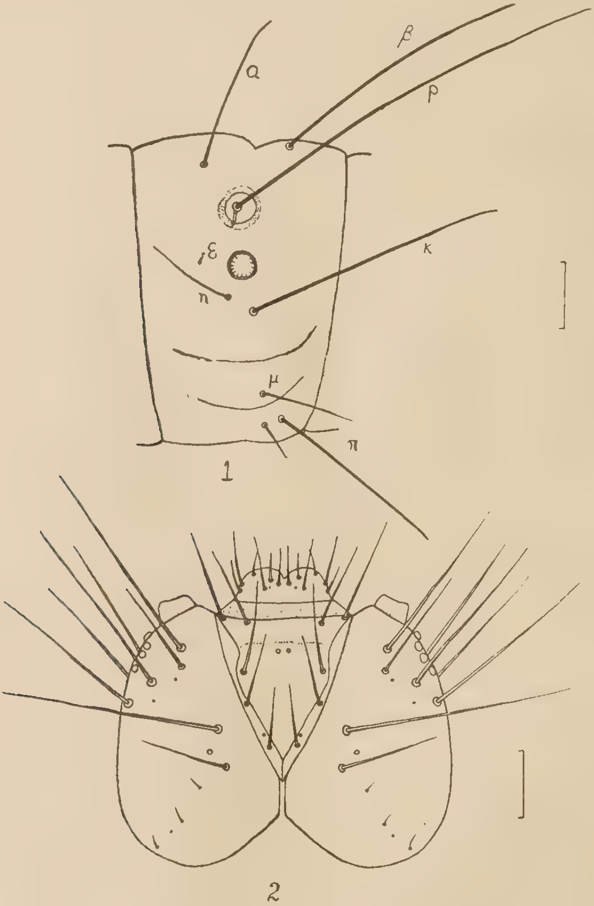
*All of the characters mentioned here can be seen with a hand lens (mag. ×15).

3. Eighth abdominal segment with seta epsilon (fig. 3, ε) separated from spiracle by considerably more than the diameter of the latter .... *E. kühniella*, Zell.

   Eighth abdominal segment with seta epsilon (fig. 4) separated from spiracle by less than the diameter of the latter.................................... *E. cautella*, Wlk.



Figs. 1–2. *Plodia interpunctella*, Hb. : (1) lateral view of eighth abdominal segment ; (2) dorsal view of head.

Key to First Stage Larvae.

1. Prothorax with tergal sclerotised plates absent............ *P. interpunctella*, Hb.

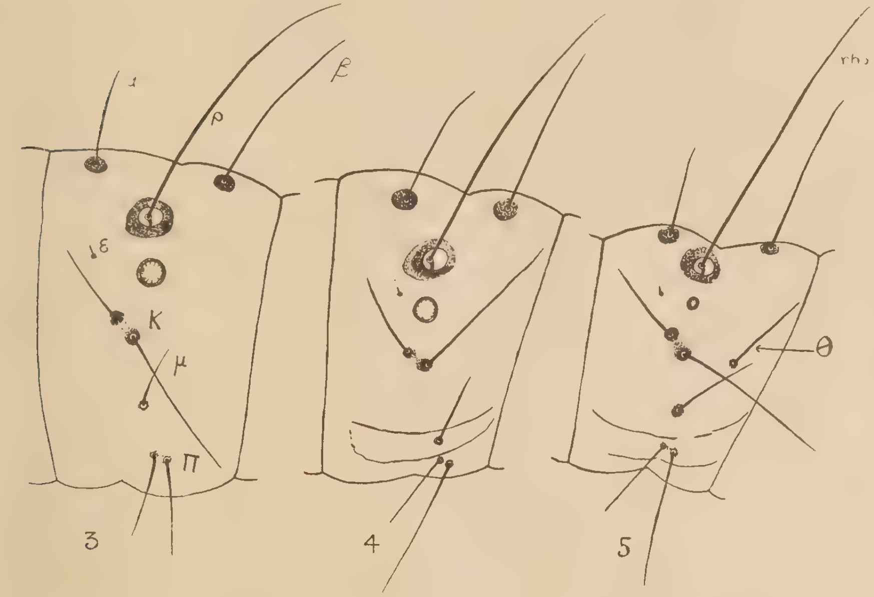
   Prothorax with tergal sclerotised plates present..2

2. Eighth abdominal segment with seta epsilon separated from spiracle by a distance equal to the diameter of the latter or less.................. *E. cautella*, Wlk.

   Eighth abdominal segment with seta epsilon separated from spiracle by a distance equal to more than the diameter of the latter..............................3

3. Spiracle of prothorax with diameter slightly less than distance between Kappa setae. Some tubercles of thorax and abdomen bearing fine apical hairs, each of which is about as long as its respective tubercle (fig. 10).........*E. elutella*, Hb.

   Spiracle of prothorax with diameter slightly greater than distance between Kappa setae. Tubercles of thorax and abdomen never with long and fine hairs, occasionally with a very short and scarcely visible (oil immersion) apical hair (fig. 11)..*E. kühniella*, Zell.

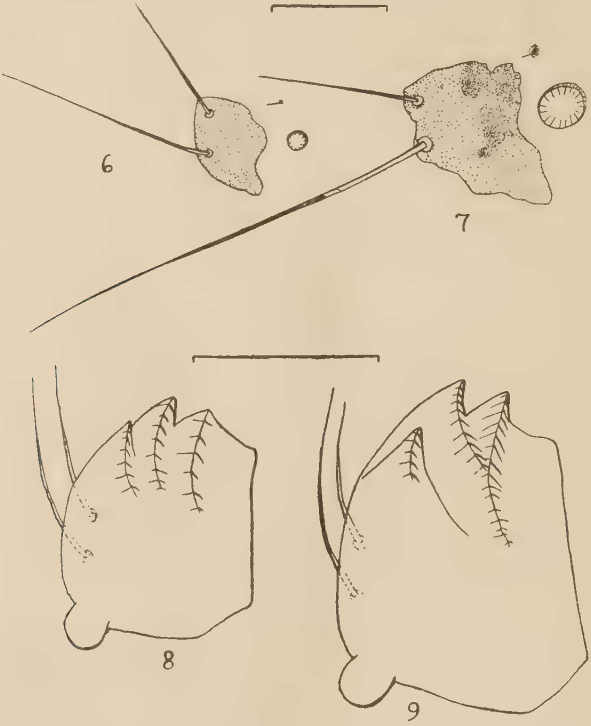


Figs. 3–5. (3) Lateral view of eighth abdominal segment of *Ephestia kühniella*, Zell. ; (4) same of *E. cautella*, Wlk. ; (5) same of *E. elutella*, Hb.

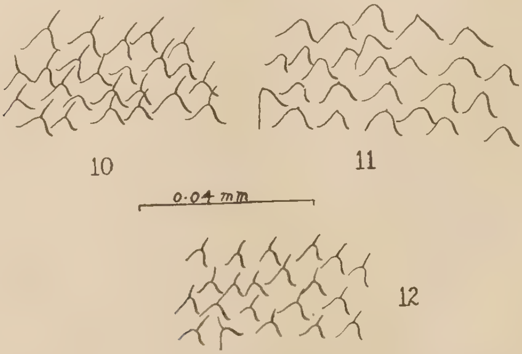
The larva of *E. kühniella* has from three to five instars (Richards & Thomson, 1932), and the last one or two (possibly the last three when there are five instars) can easily be distinguished from *E. elutella* by the relatively larger eighth abdominal spiracle. In the first and second, and possibly in the third when the total number of instars is five, the eighth abdominal spiracle is relatively the same size as in the corresponding instars of *E. elutella*. In these instances the larvae of the two species can be distinguished by comparing the diameter of the prothoracic spiracle with the distance between the Kappa setae, although this difference in the diameter of the spiracle is not so evident as in the later instars (*cf*. figs. 6, 7). However, if the mandibles are dissected out, an easily seen and constant difference will be found between the earlier instar larvae of the two species. In *E. kühniella* the outer tooth (fig. 9), when seen from an inner ventral view, does not form part of the outer margin of the mandible, this margin being formed by the outer margin of the second or largest tooth. In *E. elutella*, on the other hand, the outer tooth (fig. 8) forms part of the outer margin of the mandible, even when this is seen from an inner ventral view.

In mature larvae of *E. elutella* the subprimary seta theta (fig. 5, θ) is sometimes present on the eighth abdominal segment. Five of 11 specimens examined possessed this seta, and in two of these it was developed on both sides. This seta was always absent in the individuals of other species examined.

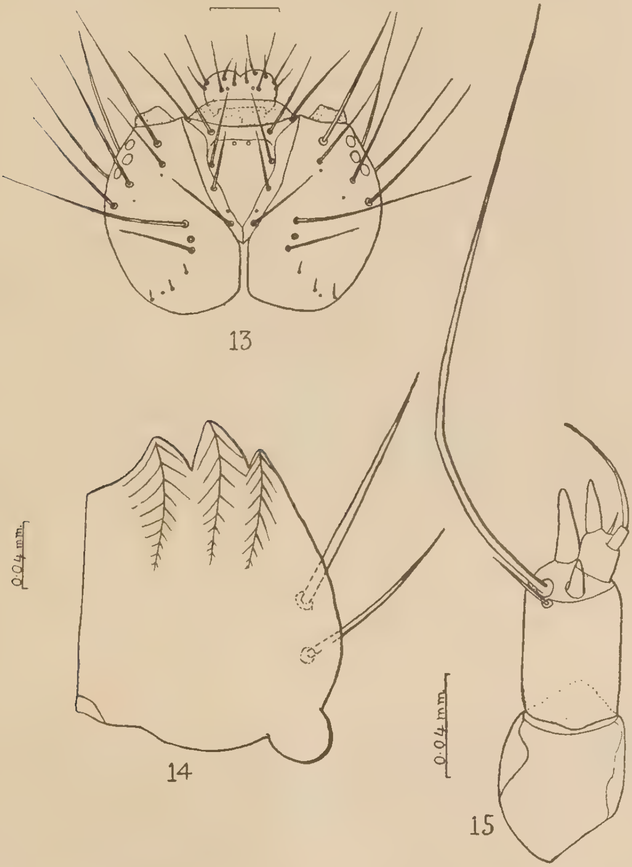
The first instar larvae of all three species may be distinguished from later instars by having only 6 to 7 uniordinal crochets on each proleg instead of about 40 to 60 biordinal crochets. Sometimes (presumably when there are five instars ?) the second instar larvae also have the crochets uniordinal, but in these instances there are always more than ten on each proleg.



Figs. 6–9. (6) Prothoracic spiracle of mature larva of *Ephestia elutella*, Hb. ; (7) same of *E. kühniella*, Zell. ; (8) inner ventral view of mandible of *E. elutella*, Hb. ; (9) same of *E. kühniella*, Zell.



Figs. 10–12. Abdominal tubercles of first stage larva of : (10) *Ephestia elutella*, Hb. ; (11) *E. kühniella*, Zell. ; (12) *E. cautella*, Wlk.



Figs. 13–15. *Ephestia figulilella,* Gregs. : (13) Head ; (14) Inner ventral view of mandible ; (15) Antenna.

The larva of *Ephestia figulilella*, Gregs., has been described by Porritt (1880). Before me is a single bred larva (figs. 13–15) which appears to be mature. It is very closely related to *E. cautella*, and I have only been able to distinguish it from the latter on two slight differences, which may prove to be of no specific importance when a good series is examined. The basal sclerites of the abdominal setae are much more feebly pigmented in *E. figulilella* than in *E. cautella,* and seta epsilon is separated from the eighth abdominal spiracle by a distance about equal to the diameter of the spiracle, whereas in *E. cautella* epsilon is nearly always separated from this spiracle by distinctly less than the diameter of the latter.

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FRACKER, S. B. (1915). The Classification of Lepidopterous larvae.—Ill. Biol. Monogr., (1) **2,** 169 pp., 10 pls.

PORRITT, G. T. (1880). Description of the larva of *Ephestia ficulella.*—Ent. Mon. Mag., **17,** p. 44.

RICHARDS, O. W. & THOMSON, W. S. (1932). A contribution to the study of the genera *Ephestia* Gn. (including *Strymax* Dyar), and *Plodia* Gn. (Lepidoptera, Phycitidae), with notes on parasites of the larvae.—Trans. Ent. Soc. Lond., **80,** pp. 169–250, 8 pls.

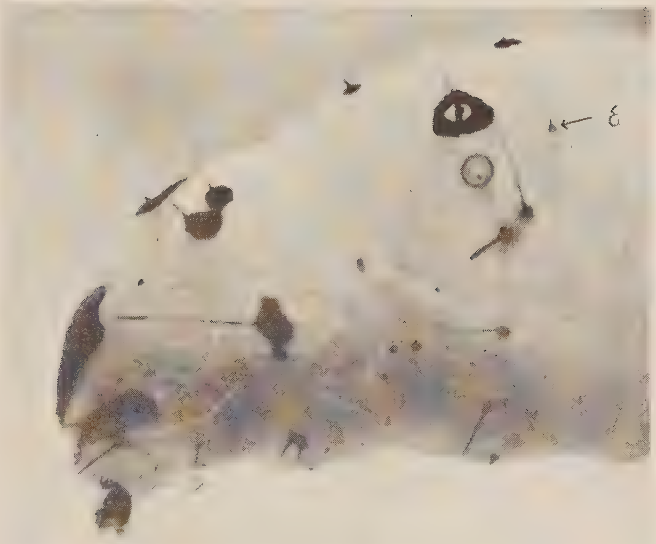

Fig. 1. *Ephestia kühniella*, Zell.

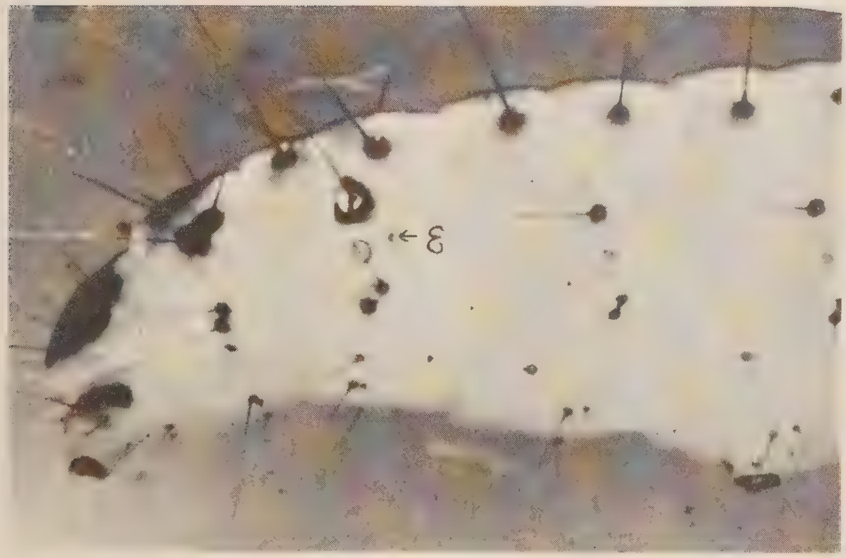

Fig. 2. *Ephestia cautella*, Walker.

A LARVASCOPE FOR USE IN IDENTIFICATION OF LIVING CULICINE LARVAE.

By J. D. Gillett.

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A lateral view of the terminal segments is essential for the identification of a Culicine larva, but owing to the necessity of the larva to pierce the surface film of the water with the spiracular valves at the distal end of the respiratory siphon, it will retain a position with the dorsal surface uppermost in spite of all efforts to induce it to do otherwise. Even if placed in water so shallow that there is insufficient space between the bottom of the container and the surface of the water for the siphon to be held erect, the insect will incline its siphon but keep the rest of the abdomen dorsum uppermost, thus possibly presenting a lateral view of the siphon, and showing the pecten, but the comb and anal segments will still not be in a suitable position for a detailed study of the characters to be made.

To anaesthetize the larva and to orientate it so as to present a lateral view would enable an identification to be made, but would probably result in the death of the larva. When replaced in its container of water, and still in a state of anaesthesia, it would be incapable of reaching the surface for its oxygen supply and would die of asphyxiation.

To isolate a representative number of larvae from a batch, kill them, identify them and assume that the remainder of the larvae in the batch are of the same species is a dangerous assumption that is likely, indeed will most probably, lead to errors. G. H. E. Hopkins (Mosquitoes of the Ethiopian Region, pt. 1, 1936, pp. 25–26) makes this clear and shows the necessity of identifying every larva from a batch ; he further suggests that unknown larvae should be bred out by the isolation method and that their pelts, plus the resultant adult, should constitute a " paedotype " when the larva is described. With this the writer is in full agreement, but it is the object of the present paper to describe an apparatus, and the technique necessary for its use, for the rapid examination of living Culicine larvae. In cases where possible new species or undescribed larvae are involved the paedotype method can be used in conjunction with the system to be described. In any case, an individual larva identified or examined in this way can subsequently be isolated and reared to the adult stage, whether the pelts are kept or not.

The principle involved is to view the larva from a position just below the surface of the water, while the larva is at rest obtaining its oxygen supply ; but owing to the bottom-browsing habits of some species, especially certain species of the genus *Aëdes*, it is necessary that certain measures be taken first to ensure that the larva will remain at rest for a sufficiently long time for all the essential characters to be noted, and (if desired) for a drawing to be made.

The larva to be examined is first placed in a glass tube containing clean water. After many experiments it has been found that a flat-bottomed tube about 5 cm. in height, by about 1·7 cm. in diameter is best suited for the purpose. The tube is filled to the brim and carefully covered with a clean glass slide, leaving no bubbles of air between the surface of the water and that of the slide. The larva is left in this " semi-asphyxiation tube " for a period of from fifteen to thirty minutes, during which time it will make frantic efforts to thrust the tip of its siphon through the surface film, only to be foiled by the presence of the glass slide above. In the case of surface-feeding species this preliminary procedure may be dispensed with, but with all bottom-feeders and browsers it is absolutely essential, if the larva is to remain at rest afterwards for any appreciable length of time.

After about fifteen or twenty minutes the slide is removed, and the larva is picked out by means of a glass pipette with a rubber teat, and placed into the larvascope cell. The size of the cell is of the utmost importance, and has been worked out carefully after much trial and error : 1·5 cm. deep × 1·5 cm. long × 2·75 mm. wide, are the measurements that have been arrived at. The walls must be of thin glass, and the apparatus can be made with two microscope slides, separated from each other by two more slides cut in such a manner as to provide the required cell (fig. 1), all four slides being cemented together with Canada balsam, or any other equally suitable cement. Or, more simply but with less precision, the apparatus can be made with two slides separated by a cell of sealing wax of the correct dimensions. The ideal, of course, would be to have the cells manufactured in one piece by some firm which specialises in such work. The larva is dropped into the cell, together with sufficient clean water to fill the cell about three-quarters full. The cell is then placed on the mechanical stage of a compound microscope, with the instrument inclined to a horizontal position. The oxygen-starved larva's first reaction is to replenish its oxygen supply, and when it has found the surface of the water with the apex of its siphon it will remain motionless at the surface for a considerable period, as though making up for lost time. When in this position the terminal segments can be viewed laterally with ease, and if a $\frac{2}{3}$ in. objective be used in conjunction with a × 10 ocular, all the essential characters may be noted. The length of time that a bottom-feeding larva will stay quiescent in this position seems to be proportional to the length of time that the larva has previously been starved of oxygen. Even such restless species as *Aëdes aegypti*, and such surface-shy species as *Culex moucheti*, have been made to hang motionless at the surface for more than thirty minutes, the larva then being isolated and bred out.

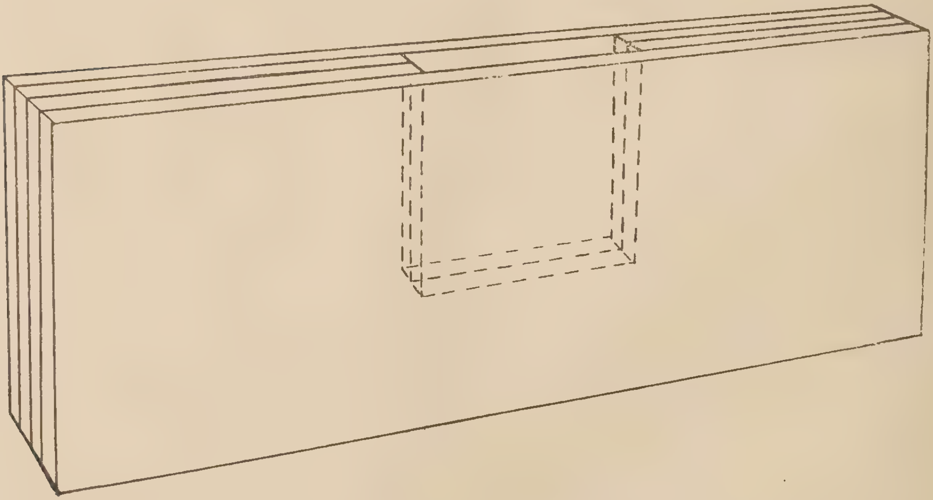

Fig. 1. The larvascope cell, made with four microscope slides cemented together, the inner pair having been cut to provide the cell.

As already pointed out, the size of the cell is important. If it is 3 mm. or more in width, the larva will be free to rotate, and will as likely as not come to rest with a dorsal or ventral view presented towards the lens of the objective. On the other hand, if it is less than 2·5 mm. in width the larva will again present a dorsal or ventral view more often than not, presumably on account of the pressure of the glass sides of the cell on the mesopleural and metapleural tufts. Occasionally, even with the optimum dimensions, the larva will present a dorsal or ventral aspect, but if disturbed it will soon come to rest in the desired position. Further, if the cell is too long, difficulty may possibly be experienced in locating a hyper-active larva before it has moved to take up a new position (although with the proper use of the semi-asphyxiation tube the possibility is remote), and if shorter than prescribed, the insect may contact the end of the cell on its upward path and will almost certainly drop to the bottom again. This procedure may be repeated more than once, thus causing much loss of time. If the cell is too deep the larva, in a more or less weakened state, will take longer to reach the surface, as several attempts may be necessary. On the other hand, if it is too shallow, the head of an elongated species such as those of the genus *Eretmapodites* may still be in contact with the bottom of the cell while its tail end has located the surface. This is undesirable, as it will more than probably have the effect of shortening the larva's visit to the surface. The size of the cell has been worked out for fourth instar larvae of average size, and has been found suitable for all species of *Aëdes*, *Culex* and *Eretmapodites* that have so far been tried. Naturally fourth stage *Megarhinus* larvae would need a larger cell, and larvae of such genera as *Uranotaenia* and *Hodgesia* a smaller one.

When practised in the use of the larvascope, and if examining larvae of a well described species, half a dozen or so larvae may be placed into the semi-asphyxiation tube at once, and after ten minutes or so one may be removed and placed in the cell for examination. On removing this larva some water will inevitably be lost from the tube, and this should be made good immediately and the glass cover replaced in order to keep the remaining larvae deprived of oxygen. Provided that the species is not an unusual one, and once the larva has found the surface of the water (which may take upwards of a minute owing to its weakened state after its experience in the semi-asphyxiation tube), identification can be made in a few seconds, and the larva placed in a special tube for the species in question. When this has been done the next larva is removed, and so on. It is not advisable, however, to place too many in the tube at once, as, if any delay occurs, the last to be removed may suffer considerably from oxygen want and lose not only its hydrostatic buoyancy but its capacity for dynamic lift as well, resulting in complete asphyxiation of the larva.*

When used as described above, after the initial period of oxygen deprivation, it should not take longer than ten or twelve minutes to examine and identify six larvae. Naturally, where an unusual species is concerned the time may be very considerably longer, but in such a case the larvae concerned should be placed in the semi-asphyxiation tube one at a time.

Summary.

A method is described for the rapid examination and identification of living Culicine larvae.

The larva to be examined is first placed into a tube of water and deprived of oxygen. After a short time the oxygen-starved larva is removed from the tube and placed in a laterally-compressed cell containing water, where it comes to rest at the surface. The larva is then examined microscopically with the instrument inclined to a horizontal position, thus presenting a lateral aspect of the larva's terminal segments.

The dimensions of the tube and cell are described, and the length of time necessary for the operation. Methods for the construction of the cell are suggested.

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* Should it be found that a valuable larva has lost its capacity to reach the surface of the water, by reason of its having been kept too long in the semi-asphyxiation tube, it may sometimes be nursed back successfully by placing it in a cavity-slide of water, enabling the insect to find the water-surface with its siphon while still lying on the bottom of the container.

NOTES ON THE GENUS *PAGRIA* (EUMOLPINAE, COLEOPT.).

By G. E. Bryant, F.R.E.S.

Entomologist, Imperial Institute of Entomology.

The genus *Pagria*, as will be seen from the following records, contains many injurious species feeding on various species of beans, etc. These have all been forwarded to the Imperial Institute of Entomology from time to time for identification :—

Pagria flavopustulata, Baly.—Trans. Ent. Soc. Lond., **1874**, p. 169. Singapore, 1919 (J. H. Burkill), attacking bean leaves.

Pagria signata, Mots.—Etud. Ent., **7**, 1858, p. 110. Ceylon, 10.vi.1928 (Dr. J. C. Hutson), on *Phaseolus* sp. ; Java, Buitenzorg, 3.i.1933, on *Vigna* sp.

Pagria kanarensis, Jac.—Ann. Soc. Ent. Belg., **39**, 1895, p. 279. Ceylon, 30.i.1925 (F. P. Jepson), on cowpea leaves (*Vigna catjang*).

Pagria sumatrensis, Lef.—Notes Leyd. Mus., **9**, 1887, p. 260. Malay Peninsula, 27.vi.1932 (G. H. Corbett), on *Dolichos hosei*.

Pagria aeneicollis, Lef.—Notes Leyd. Mus., **12**, 1890, p. 181. Serdang, F.M. States, 12.ix.1925 (G. H. Corbett & B. A. R. Gater), adults feeding on *Vigna oligosperma* ; Java, Buitenzorg, 22.i.1924 (P. v. d. Goot), on *Crotalaria*.

Pagria vignaphila, sp. n.—New Britain, Rabaul, 5.i.1941 (J. L. Froggatt), feeding on cowpea foliage.

Pagria gossypii, Bry.—Stylops, **2**, 1933, p. 253. Ibadan, Nigeria, 19.viii.1925 (F. D. Golding), on cotton.

Pagria suturalis, Lef.—Ann. Soc. Ent. Fr. (6) **4**, 1884, Bull. p. lxvii. Uganda, Kabete, ix. 1933 (H. Hargreaves), on bean, *Phaseolus lunatus*.

It is impossible to give a satisfactory key to the species, as Pic has created confusion by describing eight species and three varieties, six of which are probably varieties of *P. signata*, Mots. There is no doubt that *P. signata*, Mots., is a very variable species, and may prove to have a wide range from Japan to Java, but without seeing the types of Lefevre and Pic it is unwise to sink species on their very inadequate descriptions. I can place them provisionally in six groups, as follows :—

Oriental and Australian species.

Group 1.—Testaceous ; head, thorax, suture of elytra and two spots below the base black or aeneous ; sides of prothorax angled behind the middle : *P. signata*, Mots., var. *innotata*, Pic, var. *anceyi*, Pic, var. *rufithorax*, Pic, *kanarensis*, Jac., *burmanica*, Jac., *sumatrensis*, Lef., *aeneicollis*, Lef., (*Nodostoma*) *grata*, Baly, *vignaphila*, sp. n., *minor*, Pic, *ceylonica*, Pic, *ingibbosa*, Pic, *plicata*, Pic.

Group 2.—Sides of prothorax angled behind middle ; almost entirely black, with a small flavous stripe at the base of the elytra : *P. xanthopus*, Har., n.n. for (*Nodostoma*) *fulvipes*, Baly, nec Mots., *australis*, sp. n., *flavopustulata*, Baly.

Group 3.—Sides of prothorax angled behind middle ; a large round flavous raised spot at the base of the elytra : *P. bipustulata*, Baly, *bipunctata*, Lef., *graphica*, Wse., *muiri*, sp. n.

Group 4.—Rugose metallic species, with sides of the prothorax rounded : *P. costatipennis*, Jac., *restituens*, Wlk., *viridiaenea*, Gyll.

Group 5.—Large species, very nitid, with sides of prothorax feebly rounded and contracted in front : *P. laevifrons*, Jac., *conglomerata*, Jac., *aenescens*, Jac., *incerta*, Pic, *pallidicolor*, Pic.

African species.

Group 6.—*P. varians*, Lef., *suturalis*, Lef., *liturata*, Lef., *gossypii*, Bry.

The types of the new species are in the British Museum.

EUMOLPINAE.

Pagria vignaphila, sp. n. (fig. 1).

Head, prothorax and underside coppery, basal segments of the antennae, legs and elytra flavous, the sutural margin dark, and a rufous patch below the base of the elytra. L. 2·5 mm.

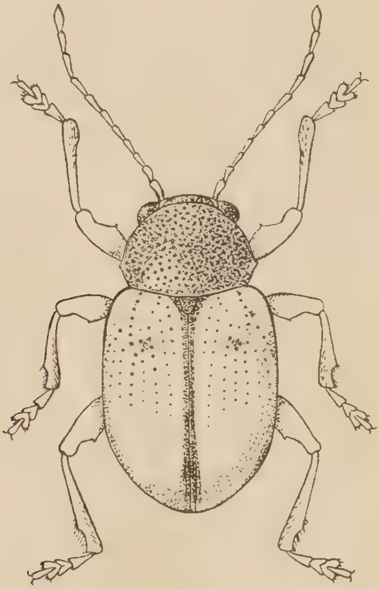

Fig. 1. *Pagria vignaphila*, sp. n.

Head coppery, strongly but not closely punctured, transversely impressed between the eyes, a short longitudinal median impression on the vertex, clypeus fulvous. Antennae slender, extending to about the middle of the elytra, the four basal segments flavous, the segments 5 to 7 flavous with the apical third fuscous, the four terminal segments fuscous, the basal segment the longest and more dilated than 2, 2 slightly shorter than 1 and a little longer than 3, 3–11 all about equal. Prothorax coppery, transverse, the sides angulate a little behind the middle, strongly but not closely punctured. Scutellum coppery, impunctate, triangular. Elytra wider at the base than the prothorax, the sides parallel and rounded at the apex, flavous, the suture narrowly dark coppery, the side margins slightly rufous, and a small rufous patch below the base, punctate-striate, but impunctate near the shoulders, the punctures in the striae somewhat widely spaced. Legs flavous, the femora with a minute tooth, the middle and posterior tibiae with their outer margin strongly emarginate at the apex. Underside coppery.

NEW BRITAIN: Rabaul, Kerawat, 2.i.1941 (*J. L. Froggatt*), 2 specimens. Reported feeding on the foliage of cowpea.

Allied to *P. aeneicollis*, Jac., from Java, but differs in the much stronger punctuation of the prothorax, and the elytra not so strongly punctate-striate, the antennae with the terminal segments fuscous, and the basal patch on the elytra rufous. Size slightly larger.

Pagria australis, sp. n. (fig. 2).

Black, nitid ; the labrum, antennae, legs and a short stripe at the base of the elytra flavous ; prothorax strongly punctured, the elytra punctate-striate. L. 2 mm.

Head black, strongly punctured, the punctures coarser towards the base, the labrum flavous. Antennae flavous, the six terminal segments tinged with fuscous, scarcely reaching the middle of the elytra, the two basal segments slightly more dilated and about equal, the palpi flavous. Prothorax black, nitid, strongly punctured, the punctures stronger and closer at the sides, transverse, the sides angulate behind the middle. Scutellum black, impunctate, triangular. Elytra broader at the base than the prothorax, the sides parallel and rounded at the apex ; black, nitid, a short flavous stripe at the base inside the shoulder, the apex of the elytra tinged with fulvous ; punctate-striate, but becoming very feeble towards the apex, the intervals flat and nitid. Legs flavous, the femora armed with a small tooth. Underside black, the ventral segments of the abdomen all short and about equal, very finely punctured.

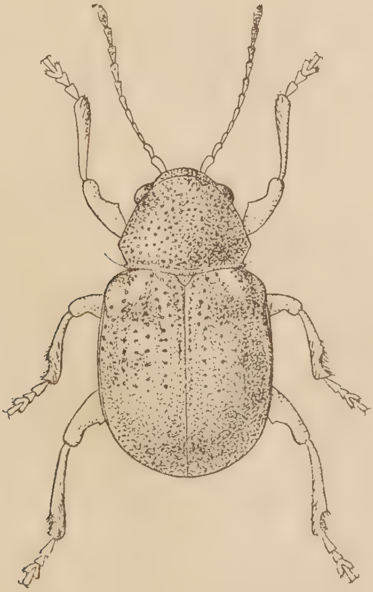

Fig. 2. *Pagria australis*, sp. n.

S.E. QUEENSLAND : Tambourine Mts., 26.iv.1935 (*R. E. Turner*), 3 specimens.

Allied to *P. xanthopus*, Har. (=*Nodostoma fulvipes*, Baly), but colour darker, a larger and broader insect, punctures of prothorax stronger, and those on the elytra finer.

16 5'

Nodostoma xanthopus, Har. (=*Nodostoma fulvipes*, Baly) and *N. grata*, Baly, must both be transferred to the genus *Pagria*.

Pagria muiri, sp. n. (fig. 3).

Black, with fulvous markings ; head with fulvous V-shaped patch, front and side margins of prothorax fulvous, elytra with the base and shoulders fulvous, a longitudinal fulvous stripe not touching the suture, antennae and legs fulvous. L. 2·5 mm.

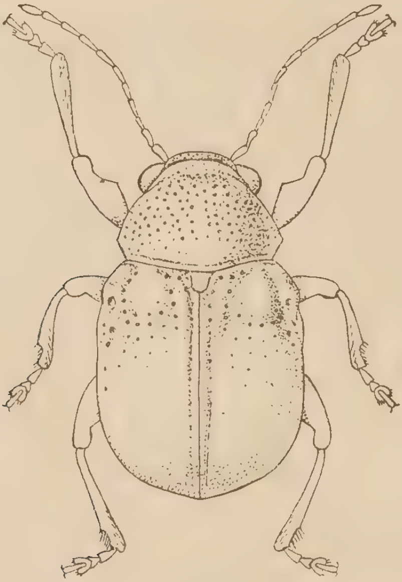

Fig. 3. *Pagria muiri*, sp. n.

Head blackish, a fulvous V-shaped patch on the vertex, the labrum fulvous, strongly punctured, a short longitudinal impression on the vertex, a deep sulcus near the eye. Antennae fulvous, not quite reaching the middle of the elytra, the first segment the longest and more dilated. Prothorax transverse, sides angled behind the middle, the anterior margin broadly fulvous, the lateral margins narrowly tinged with fulvous, strongly punctured, but almost impunctate above the basal margin. Scutellum black, triangular, impunctate. Elytra black, the base with a large fulvous patch near the scutellum, and a small one on the shoulder, a longitudinal fulvous stripe not touching the suture, a fine row of punctures parallel to the suture extending only half the length of the elytra, transversely depressed behind the base, containing a few large punctures, the apical two-thirds of the elytra nitid and almost impunctate, the sides parallel and rounded at the apex, a strong carina extending from the shoulder to the middle of the side margin. Legs fulvous, the femora armed with a small tooth. Underside black, nitid, the ventral segments 2 to 4 about equal.

Larat : xii.1907 (*F. Muir*), 9 specimens.

This is somewhat allied to *P. bipustulata*, Baly, from Borneo, but is a larger and broader species, with the punctuation different. This is evidently a very variable species, tending to become almost entirely fulvous, with the suture and the depression behind the base of the elytra black.

THE OCCURRENCE OF *ANOPHELES MARTERI* IN SYRIA.

By Major H. S. Leeson, R.A.M.C.

This Anopheline was first found in Syria in the larval stage on 30th August 1941. Up to the time of writing, 11th October 1941, adults and larvae have been taken on several occasions. Isolated larvae have been bred to the adult stage, and larval and pupal pelts preserved. Through the courtesy of Professor S. Adler and Dr. O. Theodor, of the Hebrew University at Jerusalem, I was able to consult the literature regarding the distribution of this species and to confirm its identification. The discovery of *Anopheles marteri* in Syria is a new record.

In their original description (Senevet & Prunelle, 1927) the authors omit one or two details ; for example, they do not mention the pale fringe scales at the apex of the wing, and they say that the larva has no palmate hairs on the thorax. These statements are corrected in a subsequent paper (Senevet, 1932) ; a later publication (Senevet, 1935) gives a full description of adult, larva, and pupa. The egg is described by Hadjinicolaou (1938) who recorded the species from Greece. A Russian paper with a summary in English (Keshish'yan, 1938) describes a new species (*A. sogdianus*) which the author says is near *A. marteri*. This paper was not seen in the original. A description of *A. marteri* as it occurs in Syria follows :—

Adult.—Female : palpi dark brown, smooth, unbanded. Vertical tuft present, with creamy coloured scales. Mesonotum greyish brown, with a faint median dark longitudinal line, ashy grey on each side of line, no scales, hairs only. Femora and tibiae dark. Hind tarsi with no pale bands. Wings unspotted. Apex of wing with a pale fringe spot. Pale fringe spots absent elsewhere. Abdomen with hairs only. Cerci with hairs only.

Male : nothing special to note in external characters. Hypopygium with two parabasal spines ; inner, a little shorter but about the same thickness as outer, bent at tip ; outer, straight, not bent or hooked ; one internal spine about middle of coxite ; harpagones with three flattened spines ; phallosome long, narrow, with a large number of leaflets.

Pupa.—Paddle narrowing towards apex, where paddle-hair arises ; no black spot at tip ; a fringe of long hairs on margin except near the bases ; length of fringe hairs one-half to three-quarters length of paddle-hair ; paddle-hair stout, slightly curved with very small hook at tip ; accessory paddle-hair very short, simple, or with one or two branches. Spine short and blunt ; III minute ; IV–VII increasing in length ; VIII with 8–12 branches, some branches may be split into two, accessory hair simple or bifid. Hair B as long as or a little longer than segment, 4–8 branches, some branches may be split into two or three. Hair C about as long as segment ; IV–V with 8–10 branches ; VI–VII with 4–7 branches. Hair C1 on V1 very short, about one-eighth as long as C, fine, bifid.

Larva.—Fronto-clypeal markings very patchy, indistinct and sometimes absent. Inner clypeal hairs with bases nearly touching, simple. Posterior clypeal hairs simple. Outer clypeal hairs simple. Frontal hairs weak, short, reaching only to bases of posterior clypeals, 4–6 branches. Post-frontal hairs short, simple, or bifid. Apical antennal hair often simple, may have two or three branches, longer than blades. Shaft hair near base, 1–4 branches. Shoulder hairs : inner, ¼ length of middle, about nine branches, tubercle inconspicuous ; middle, fairly well-developed, 8 branches, tubercle distinct. Propleural hairs three, long, simple ; mesopleural two, long, simple. Metapleural hairs two, long, simple. Basal spines small. Thoracic palmate hairs present, leaflets without shoulders, produced into fine filaments, about 14 leaflets. Abdominal palmate hairs ; I an ordinary branched hair ; II–VII fully developed, about 23 leaflets with shoulders and long terminal filaments. Tergal plates : I wider than II ; II–VII increasing in width ; VIII considerably wider and deeper than VII ; one accessory plate only. Saddle hair thin, simple, shorter than normal, only about as long as or even shorter than the saddle itself, base on saddle. Pecten with 18–24 teeth.

Egg.—" Uniformly black and resembles in some degree that of *A. claviger* (*bifurcatus*). It may be distinguished by the very large floats, which are more than three-fourths of the total egg-length ; the middle of the float at its broadest central part is one and one-half times the width of the ventral surface of the egg, which is seen between the two floats. The number of ribs, counted in the floats of 10 eggs, averaged 26, varying from 23 to 29 ribs per float. The intercostal membrane of the float structure of *A. marteri* is moderately ridged or rough, while that of *A. claviger* (*bifurcatus*) is smooth " (Hadjinicolaou).

Some characters by which *A. marteri* may be distinguished from *A. claviger* and *A. algeriensis* :—

	claviger	*algeriensis*	*marteri*
Adult			
Vertical tuft	present	absent	present
Mesonotal tuft ...	present	absent	absent
Mesonotal clothing ...	golden hairs or scales	long dark hairs	long dark hairs
Apex of wing	fringe scales dark	fringe scales dark	fringe scales pale
Larva			
Fronto-clypeal markings	spots	bands	indistinct
Anterior clypeal hairs	sometimes barbed	sometimes barbed	always simple
Posterior clypeal hairs	branched	branched	simple
Frontal hairs	long	long	short
Abdominal palmate hairs	no filaments	no filaments	long filaments
Pupa			
Spine A	pointed	pointed	blunt
Hairs B and C... ...	short	short	long
Paddle fringe	short spines	short spines	long hairs

The breeding-places of *A. marteri* in Syria are of the same kind as those described by Senevet for North Africa and by Hadjinicolaou for Greece. It is a species which lives in hilly or mountainous country. It has been found in Syria at altitudes of from 400 to 4,000 feet. Larvae and pupae have been found in shaded pools in steep and rocky stream-beds. In the streams are cascades and waterfalls, rapids and torrents, with the shady pools at intervals, sometimes at the sides. The larvae often come out into the open parts of the pools and are easily seen and may be dipped out in numbers. When once disturbed, however, they get among the boulders or under overhanging rocks, and may be missed by the collector.

Seven species of *Anopheles* have now been recorded from Syria. Keys to the identification of these species follow :—

Adults.

1. Spots on wing..2
 No spots on wing..5
2. Dark spots in middle of wing only..*sacharovi*
 Dark and pale spots on costa as well as in middle of wing...........................3

3. Costa with fewer than four pale spots..*hyrcanus*
   Costa with four or more pale spots..4
4. Hairs and scales on mesonotum..*superpictus*
   Hairs but no scales on mesonotum..*sergenti*
5. Mesonotum with golden hairs or hair-like scales on median area and with tuft of pale scales on anterior border..*claviger*
   Mesonotum with dark hairs only and no scales..6
6. Tuft of pale scales on vertex, pale fringe scales at apex of wing...........*marteri*
   No tuft of pale scales on vertex, and no pale fringe scales at apex of wing........... *algeriensis*

Larvae.

1. Inner clypeal hairs, bases nearly touching..2
   Inner clypeal hairs, bases wide apart..6
2. Outer clypeal hairs tree-like..3
   Outer clypeal hairs not tree-like..4
3. Inner clypeal hairs simple ; branched antennal hair arising halfway along shaft .... *hyrcanus*
   Inner clypeal hairs branched towards end ; branched antennal hair arising quarter way along shaft..*sacharovi*
4. Abdominal palmate hairs without filaments..5
   Abdominal palmate hairs with filaments..*marteri*
5. Dark markings on fronto-clypeus, separate spots ; base of saddle-hair at edge of or off saddle..*claviger*
   Dark markings on fronto-clypeus, transverse bands ; base of saddle-hair within margin of saddle..*algeriensis*
6. Dark transverse band on fronto-clypeus about bases of frontal hairs ; main tergal plates wider than gut ; three accessory tergal plates..............*sergenti*
   Small dark spot behind frontal hairs ; main tergal plates not wider than gut ; only one accessory tergal plate..*superpictus*

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BIOLOGICAL CONTROL OF *DIATRAEA MAURICIELLA*, WLK.,* IN MAURITIUS.—I. INVESTIGATIONS IN CEYLON IN 1939.

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CONTENTS.

PAGE
1. Introduction 39
2. Previous records of *Diatraea* in Ceylon 41
3. Distribution of sugar-cane, with notes on the sugar industry 41
4. Occurrence of *Diatraea venosata*, Wlk., as revealed by the present work 43
5. Parasites and diseases of *Diatraea venosata* 44
6. Occurrence of *Chilo zonellus*, Swinh. 45
7. Parasites and diseases of *Chilo zonellus* in Ceylon 45
    - (i) *Xanthopimpla stemmator*, Thunb. 46
    - (ii) *Bracon albolineatus*, Cam. 49
    - (iii) *Apanteles flavipes*, Cam. 53
    - (iv) *Macrocentrus* sp. 54
8. The shipment of borer parasites to Mauritius, their rearing, liberation and establishment 54
    - (i) *Xanthopimpla stemmator*, Thunb. 55
    - (ii) *Bracon albolineatus*, Cam. 57
    - (iii) *Trichogramma evanescens*, Westw. 61
9. Summary 63
10. Acknowledgments 64

1. Introduction.

The Sugar Industry of Mauritius is suffering heavily from damage by stem-borers, especially the "Spotted Borer," *Diatraea mauriciella*, Wlk. It has been estimated (Moutia, 1934) that this species alone is responsible for an average reduction of 15 per cent. in the field, per arpent, and that the loss in sugar averages 2·3 per cent., *i.e.* 16 per cent. of the sugar in cane. This means a gross loss of about 1½ million rupees per annum for the whole island, or a net loss of approximately 125,000 rupees.

It must be explained that the moth-borer called here *Diatraea mauriciella* has been confused hitherto with *Diatraea venosata*, Wlk. It was believed that the two names were either synonyms, preference being given to *venosata* more or less on the principle of "nomen conservandum," or, synonymous or not, it was thought that the species damaging sugar-cane in Mauritius was identical with the one known in India, Indo-China, Formosa, etc., as *Diatraea venosata*. But quite recently (January 1941) the writer on examining the male genitalia figures of *D. venosata* published by B. D. Gupta (1940) was surprised to see that the Mauritian species was certainly

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*[The correct name of this species is *Proceras sacchariphagus*, Bojer 1856, and all the Old World species of *Diatraea* should be transferred to *Proceras*, Bojer (see paper by Mr. W. H. T. Tams, p. 67.)—Ed.]

distinct from it. A dissection of the two male *Diatraea* specimens obtained by the writer on sugar-cane in Ceylon was then made ; they were found to be also positively distinct from the Mauritian species and identical with the Indian *D. venosata*.

Examples of *Diatraea striatalis*, Sn., from Java, kindly communicated by Dr. Van der Goot, were also dissected and found to agree with the Mauritius *Diatraea*, and it therefore appears necessary to consider *D. striatalis*, Sn. 1890–91, not as a synonym of *D. venosata*, Wlk., but of *D. mauriciella*, Wlk. 1863, or at most as a distinct sub-species or race of the latter on account of a few minor differences in the shape of the genitalia. Thus the Mauritius *Diatraea* probably comes from Java, which supplied Mauritius with a large consignment of cane-tops in 1850. In a recent paper the writer (Vinson, 1941) has endeavoured to put forward the evidence supporting such conclusions and intends to publish later figures of the various genitalia which could not be printed locally in the present circumstances. The error seems due to a superficial identification of the Mauritian species in the past, probably coupled with the fact that the hypothesis that it had been introduced from Ceylon in 1848 with a consignment of cane-tops, as related by d'Emmerez de Charmoy (1917) and others, had been blindly accepted.

So deeply rooted in all minds was this conjecture that when it was decided in 1938 to investigate the biological control of *Diatraea* in Mauritius by importing parasites from abroad, Ceylon was selected in the first instance. In view of the fact that, although present in that country, *Diatraea* is not at all a prominent pest there, either on sugar-cane or on rice, it was thought that this insect was possibly held in check by natural enemies that could be found and imported into Mauritius. In consequence, with the aid of a grant from the Colonial Development Fund, the writer was detailed by the Mauritius Department of Agriculture to investigate this question. He left Mauritius on 5th December 1938, arrived in Ceylon, via Bombay, on 25th December and remained there up to 5th July 1939. The investigations thus covered a period of six months.

After some preliminary investigations it was soon realised that although *Diatraea venosata* was really present in Ceylon, it was so scarce that little hope could be entertained of finding it in adequate numbers, even to determine its degree of parasitism. It was therefore decided, apart from a constant search for this insect in all possible habitats, to devote attention to the other Lepidopterous stem-borers of Ceylon likely to harbour parasites which might be useful against *Diatraea* in Mauritius.

Of the various Pyralid moths known to attack graminaceous stems in Ceylon, those of the genus *Chilo* are the nearest relatives to *Diatraea*. It will be remembered here that the two genera can only be distinguished by the fact that in *Diatraea* vein 11 of the forewing (Sc) is anastomosed with vein 12 (R1), whereas in *Chilo* these veins are not anastomosed but closely approximated. The two genera are so much alike superficially that they have been frequently confused in the past. For instance *Diatraea venosata* was originally described by Walker in 1863 as *Chilo venosatus*, and even nowadays it is not at all certain that it is in its right place in the genus *Diatraea*. Box (1931) is of opinion that this genus should be reserved for the Neotropical species, whilst *venosata* and the other Old World species should be placed in another genus to be created for this purpose.

Finally, it will be useful to note that *Diatraea venosata* is very much like *Chilo zonellus* in size, and this is often an important factor when parasites are concerned. *Chilo zonellus*, Swinhoe 1884, is the species commonly found in India and Ceylon, which was for long known as *Chilo simplex*, Butl. It has been subsequently established that these two species are not only distinct, but that the name *C. simplex*, Butler 1880, must be sunk as a synonym of *C. supressalis*, Walker 1863, the species occurring in China, Japan, the Philippines, Hawaii, etc.

Chilo dichromellus, Wlk., is another species occurring in Ceylon. It is much smaller in size than *C. zonellus* and it is comparatively rare, only a few larvae having been observed on rice by the writer on one occasion. On account of this scarcity its parasites were not studied, so that *Diatraea venosata* and *Chilo zonellus* will be the only two species dealt with in the present paper.

2. Previous Records of Diatraea in Ceylon.

In a list of the pests of cultivated plants in Ceylon published by the Department of Agriculture of Peradeniya (1923) *Diatraea saccharalis*, F., is included amongst the insects injurious to sugar-cane. It now seems obvious that this was a misidentification, *D. saccharalis* being a typical Neotropical species not occurring in the Oriental Region, and that the insect concerned was *D. venosata*. Nowadays, from information supplied by the Government Entomologist, *Diatraea* is not considered as a pest of sugar-cane, rice or maize in Ceylon. The insect was not even represented in the economic collections at the Department of Agriculture, where specimens and records are so carefully kept.

It was only in the rich systematic collections of the Colombo Museum that one example of a *Diatraea*, from Lunugala, labelled "*Diatraea saccharalis*," could be seen. This unique specimen is old and in an indifferent state of preservation. Although for the reasons given above it seems quite improbable that it is really *D. saccharalis*, it cannot nevertheless be ascribed with certainty to *D. venosata*. Its size is much smaller and its general build appears different. Definite identification seems impossible without dissection.

It is needless to add that nothing was known about the natural enemies of *Diatraea* in Ceylon, the host insect itself being so rare.

It was with such a scanty outlook on the subject that the writer started his investigations. First of all he had to gather an idea of the distribution of sugar-cane in Ceylon. Though this plant is a quite familiar sight there, isolated tufts being seen growing near the huts of natives everywhere for chewing purposes and use in "aryudevic" drugs, true plantations are very scarce. . They are found only in a few definite localities of the island which had to be determined exactly.

3. Distribution of Sugar-cane, with Notes on the Sugar Industry.

Nowadays cane sugar manufacture can hardly be termed an industry in Ceylon. Its promotion was being considered by the Ceylon Government. In 1939 not more than 150–200 acres of the island were planted in cane grown for sugar. Of these, 100 to 125 acres were to be found in the Galle District, in the south-west of the Island, and 50 to 75 acres near Haldumulla, in the Uva Province. Apart from that, a few sugar-cane fields could be seen here and there : at the Experimental Station of the Department of Agriculture at Peradeniya there was a trial plot of about one-fourth acre ; at Kiliveddi, in the north-east, an experimental plot of half an acre for the Department of Agriculture was also seen ; at Badalla some small fields /u occurred, totalling about 1½ acres.

(i) *Galle District* (*Southern Province*). Sugar-cane is grown there mostly in a region where the average annual rainfall is 125 to 150 inches. Some plantations were found in the 100 to 125 inches zone and others in the 150 to 200 inches. The average temperature of the region is 80°F. (26·7°C.). All the plantations are in the low country, *i.e.* not above 100 ft. elevation.

As already stated, from 100 to 125 acres of sugar-cane were to be found in the region in 1939, but it is said that at one time cultivation was much more intensive there, reaching nearly a thousand acres. Several planters gave up planting, but a number of village Sinhalese families are still growing sugar. The plantations are much scattered in the region and are found almost exclusively on the elevated banks of the

Gin Ganga river. They are often of difficult access, as no proper bridges exist on the river. In most cases transport of canes to the mills is effected on the water, by means of rafts. The villages of Nagoda, Mapalagama, Unanwittiya and Keppitiyegoda, are the places where the more important plantations were seen.

The industry is still in a very primitive state there. The factories consist in a small mill worked by one or two pairs of bullocks walking round a circular trail. The canes are fed by hand one by one, and the expressed juice flows out through a gutter into a series of three or four cauldrons, where it is boiled, limed and concentrated. The syrup thus obtained is transferred to a cooling tank, where the sugar eventually crystallises. It is then carried outside and spread out to dry in the sun.

Since the canes are not weighed it is difficult to gather an exact idea of the extraction of sugar per cent. cane. One of the mill-owners roughly estimated this extraction as being 1½ cwt. of sugar per ton of cane. This means an extraction of about 7·5 per cent. Another one declared 16 cwt. of sugar per acre of cane (in Mauritius 2 tons of sugar per acre is the average figure.).

The growth of sugar-cane is apparently rather satisfactory, on the whole, in the Galle District. The varieties grown are, however, of a such degenerated type—they are believed to be old Mauritius varieties introduced nearly 150 years ago—that much better results can hardly be expected. Gumming disease was most frequently observed during the survey made by the writer in these localities ; some fields were severely affected by this disease, several stools dying out. On the other hand, insect pests do not seem to be particularly troublesome. Of the fifteen kinds of insects recorded from sugar-cane by the Department of Agriculture, only one appeared to be fairly abundant in Galle and probably causes a certain amount of damage. It is the plant-sucking bug, *Pyrilla aberrans*, Kirby.

The status of stem-boring caterpillars was found to be almost negligible, as will be seen by the figures quoted in another section of this paper. The plantations seem to be free from white grubs. Their absence, as well as the comparative scarcity of other insect pests, has probably something to do with the non-intensive cultivation of sugar-cane and to the cultural methods in use. According to information gathered *in situ*, sugar-cane is allowed to ratoon only once. The stumps are then removed and another kind of crop such as manioc or rice is planted.

(ii) *Haldumulla* (*Uva Province*). Average annual rainfall 75 to 100 inches ; average temperature 70 to 72°F. (21–22°C.) ; altitude 2,000 to 3,000 ft. above sea-level.

The area of cane grown there is roughly estimated from 50 to 75 acres and is therefore next to Galle in importance. It was noticed that cane growth is exceedingly poor in the region. Insects pests seem to be almost absent, but the stems are heavily damaged by squirrels. The sugar industry is more primitive than in Galle, and the crushing mills are still smaller in size. The plantations are mostly owned by Tamil Indians.

(iii) *Badulla* (*Uva Province*). Average rainfall 75 to 100 inches ; average temperature 80°F. (26·7°C.) ; altitude 1,000 to 2,000 feet.

A few plantations, totalling about 1½ acres, were seen near this town, along the banks of one of the tributaries of the Mahaweli Ganga. Sugar-cane seems to grow very well in this locality, but the stalks are not used for making sugar.

(iv) *Kiliveddi* (*Eastern Province*). Average rainfall 50 to 75 inches ; average temperature 81–82°F. (27·2–27·7°C.) ; altitude 50 feet.

The Department of Agriculture has here an experimental plot of half an acre planted in P.O.J. 2878, the growth of which looked highly satisfactory. In the vicinity and scattered along the road to Trincomalee small patches of about 15 to 20 cane-stools could be seen growing vigorously near the huts of natives.

(v) *Peradeniya* (*Central Province*). Annual rainfall 88 inches ; average temperature 76°F. (24·4°C.) ; altitude 1,550 feet.

Approximately one-fourth of an acre of sugar-cane was grown at the Experiment Station of the Department of Agriculture, near the Botanic Gardens.

4. Occurrence of Diatraea venosata, Wlk., as revealed by the present Work.

Searches on Sugar-cane.

Most of the 100–125 acres of sugar-cane found growing in the Galle District were carefully and repeatedly examined during the months of February, March and April. The only field in which *Diatraea* attacks were really visible was at the Mapalagama village. It was a field of three acres about to be harvested. Counts made in that field at the end of February revealed a stalk infestation of 5 per cent. and a joint infestation of approximately 0·3 per cent. (number of attacked joints per cent. total number of joints). Only 2 per cent. of the bored stalks actually contained *Diatraea* larvae, the tunnels in the remaining 98 per cent. being empty. From the above it may be roughly calculated that this 3-acre field would not have yielded more than 45 to 50 larvae, and in fact not more than a dozen could be collected in it after several days search and a high premium offered to the natives for all those brought by them. A young plantation in the immediate vicinity of that infested field was also scrutinized, but not a single " dead heart " could be detected.

Apart from this examination of rooted canes of nearly all the plantations of the Galle District, another series was carried out on harvested stalks both in the fields and at the mills. It is considered that such examinations have yielded figures which give a fairly concrete idea of the *Diatraea* infestation of the whole region. Stalk and joint infestations of as low as 0·25 and 0·015 per cent., respectively, were thus detected. Details as follows :—

Number of stalks examined	4,340
Number of stalks attacked by *Diatraea*	11
Stalk infestion 0·25 per cent.	
Number of joints in stalks examined	73,780
Number of joints in stalks attacked	11
Joint infestation 0·015 per cent.	

During May and June investigations were carried out in the sugar-cane areas near Haldumulla (50 to 75 acres). These plantations were examined *in situ* and at the same time a certain number of harvested stalks (500) were examined near one of the small mills in operation. Both examinations were absolutely negative. In view of these facts it was considered useless to push the investigations further in the Haldumulla region.

The small plantations found at Badulla were examined in May. They were also completely free from *Diatraea*. One bored stalk was, however, found, but the insect responsible was *Chilo zonellus*.

The experimental plot of P.O.J. 2878 at Kiliveddi was carefully scrutinized, as well as isolated cane-stools growing along the road between that place and Trincomalee. *Diatraea* was also absent there, but three stalks attacked by *Chilo* were observed.

At Peradeniya, the experimental field of the Department of Agriculture was repeatedly visited, but it was always found to be free from any kind of moth borer.

Finally, opportunity was always taken to examine isolated sugar-cane plants growing in various places in Ceylon ; for instance, at Kandy, Gampaha, Hettipola (on the road to Chilaw), Minneriya, Tabbowa (near Puttalam), etc. No traces of borers could be detected in any of these places.

Searches on other Gramineae.

As is well known, *Diatraea venosata* is not exclusively restricted to sugar-cane. It is recorded on many other plants, such as *Saccharum spontaneum*, L., *Saccharum fuscum*, Roxb., *Sorghum vulgare*, Pers., *Pennisetum typhoides* (Burm.), Stapf & Hubbard, *Vetiveria zizanioides* (L.), Nash, *Panicum maximum*, Jacq., *Zea mays*, L., *Oryza sativa*, L., etc. In India it is reported as being a real pest of *Sorghum vulgare*, known as " juar " or " cholam."

Most of the above-named Gramineae were examined in Ceylon, as well as many others, such as *Sorghum durra*, Stapf, *Coix lachryma-jobi* and *Saccharum* (*Erianthus*) *arundinaceum*, Retz, but *Diatraea* was never found on any of them. *Saccharum arundinaceum* being so much like sugar-cane in size and appearance, particularly retained the writer's attention for some time. It is a wild species abundant near many Ceylon rivers, where it is the dominant species of the riparian grass associations. But no borer was ever found in its stalks, probably on account of their pithy, unpalatable nature.

With reference to the other Gramineae it must be said that no extensive areas were available for examination, with the exception of rice and maize. As already said, *Diatraea* is unknown on rice in Ceylon, although it is not impossible that it does occasionally occur, but it is probable that its presence would be easily overlooked or confused with the " white ears " symptom produced by the other common rice borers (*Schoenobius*, *Scirpophaga* and *Chilo*), which were themselves not particularly abundant on paddy during the writer's visit. As far as maize is concerned it can be positively said that *Diatraea* did not occur at all on that crop, otherwise its presence would have been certainly noticed during the course of extensive examinations made in connection with the *Chilo* parasites.

5. Parasites and Diseases of Diatraea venosata.

In view of the fact that only a dozen *Diatraea* larvae could be collected, some of which had been more or less injured through manipulation, it is not surprising that no parasites were obtained from this trifling number. As to the eggs and pupae, it is very difficult to find them in the field, even in a severely infested one. The eggs are laid on any part of the plant and their colour matches the surroundings perfectly. The pupae are concealed in the trash. These two stages were therefore not found in the very mild *Diatraea* infestation observed in Ceylon. It is noteworthy, however, that the rapid flight of an Ichneumonid, most probably referable to *Xanthopimpla stemmator*, Thunb., a pupal parasite of *Diatraea*, as was known later, was once observed by the writer in a cane-field at Galle.

In the damp and hot climate of Galle one would expect to find entomogenous fungi flourishing. In fact two or three of the *Diatraea* larvae collected showed signs of fungus disease. One of them was actually found dead in a cane-stalk, the others dying a few days after collecting, showing visible signs of fungus attack. These samples were submitted for identification to the Imperial Mycological Institute, through the Imperial Institute of Entomology, and Mr. E. W. Mason reported on them as follows :—" *Diatraea venosata*, Wlk.—one of the specimens showed a considerable number of conidiophores of an *Aspergillus* of the *A. flavus* group, which includes the Entomogenous species *A. parasiticus*, Speare. Mr. Dade, however, who specialises in this genus has been successful in isolating it, and reports that it is typical *A. flavus*, Link.

" I dissected the second specimen, and found that the body is being turned into a fungus sclerotium, and think that it is altogether probable that the really effective fungus is not showing itself outside yet."

6. Occurrence of Chilo zonellus, Swinh.

As already explained in the introductory part of this paper, *Chilo zonellus*, Swinh., is the corect name for the species formerly known in India and Ceylon as *Chilo simplex*, Butl.

The biology of this insect is well known and is essentially similar to that of *Diatraea venosata*, except that the chrysalis is formed in the larval tunnel, and not in the trash or leaf-sheaths. The host-plants include several Gramineae, of which maize, sorghum, rice and sugar-cane are the most usual in Ceylon. In general it does not seem to be a very troublesome pest there. On maize its attacks are chiefly visible on stubble left in the field after the harvest, but occasionally the cobs are also damaged. Sorghum does not seem to be intensively cultivated in Ceylon ; on one occasion a small patch of *Sorghum vulgare* was found to be heavily bored by *Chilo zonellus*, but the seeds had been almost completely reaped at that time, so that the yield could not have been much affected.

On paddy it is said to occur sporadically, though its presence is generally overshadowed by two smaller borers, which are more widely spread, *Schoenobius bipunctifer*, Wlk., and *Scirpophaga nivella*, F.

The occurrence of *Chilo zonellus* on sugar-cane in Ceylon has already been mentioned in another section of this paper. It has been seen that this insect is not abundant on that plant, only four stalks having been found attacked by it during all the survey. Consequently all the investigations to find *Chilo* parasites were centred on maize, including a small proportion of sorghum.

In Ceylon maize is generally grown during the north-east monsoon rains, *i.e.* in October–November, so that the harvest of the cobs is almost completed during the dry months of January–February. The plantations inspected by the writer from January to March in various localities consisted therefore mostly of old stubble plants drying up in many cases. The season had been abnormally dry and the crop had completely failed in many localities.

7. Parasites and Diseases of Chilo zonellus in Ceylon.

Apart from *Cremastus flavo-orbitalis*, Cam., an Ichneumonid attacking the larvae, there had been hitherto no record of parasites from *Chilo zonellus* in Ceylon. This parasite was not, however, observed by the writer, but four others were found : an Ichneumonid attacking the pupa, *Xanthopimpla stemmator*, Thunb., and three Braconids parasitising the larva, *Bracon albolineatus*, Cam., *Apanteles flavipes*, Cam., and *Macrocentrus* sp. It is rather curious to note that no Dipterous parasite was obtained.

With reference to the fungus diseases of *Chilo zonellus*, a few affected larvae were submitted to the Imperial Mycological Institute and the causative organism has been identified by Dr. Petch as *Cephalosporium indicum*, Petch.

About 3,000 infested maize stalks, which were found to contain approximately 3,700 *Chilo* larvae and pupae, were collected from January to March in the above-named places. These stalks were cut into pieces about two feet long and placed in rearing cages measuring 24 × 18 × 18 inches, provided with glass at one end and a cloth sleeve at the other. The bottom was of wood as well as one-third of the height of the lateral sides, the top and the remainder of the cage being covered with fine white organdie cloth glued on the wooden frame.

The cages thus supplied with infested stalks were closely watched on the following days, and all emerged parasites collected. After an average period of twelve days all the maize pieces were split open and the contents carefully examined. The status of any parasite observed in the cage during the previous days could thus be positively ascertained by finding out the host larval skin or pupal shell. At the same time all the full and empty *Chilo* pupae contained in the stalks were counted and examined, the full ones being again kept under observation until emergence to ascertain if they would not have yielded further parasites. Similarly the *Chilo* larvae were examined for any sign of parasitism and their breeding continued on fresh pieces of maize.

This procedure was adopted in order to avoid the risk of disturbing the eggs and larvae of any possible ectoparasite. After the 12 days delay most of the parasites contained in the material would have emerged or spun their cocoons, which are better protected than eggs or larvae against the dangers of manipulation.

Between 9.i.1939 and 27.iii.1939, 3,688 larvae and pupae of *Chilo zonellus* were collected, which when examined 12 days after collection comprised 2,046 larvae, 649 full pupae, and 993 empty pupae. The parasites obtained from this material were 15 *Xanthopimpla stemmator*, 7 *Bracon albolineatus*, 8 *Apanteles flavipes* and 3 *Macrocentrus* sp.

The numbers of *Chilo* larvae, full pupae and empty pupae given above refer to those found in the maize stalks after an average observation period of 12 days ; consequently, since the pupal stage of *Chilo* is about 10 days in Ceylon, the " full pupae " were really larvae at the time of collection and should be treated as such in working out figures of parasitism. Only the " empty pupae " would represent the actual number of pupae, hatched or not, which were in the infested stalks on the day of collection.

In the case of the pupal parasite *Xanthopimpla stemmator*, the percentage of parasitism is calculated on the number of empty pupae found on the examination day, so that parasitism by this species was only 1·5 per cent., but it must be noted that its activities are seasonal, since in January only the figure was about 4 per cent.

With reference to *Bracon albolineatus*, though it is a larval parasite, it seems unfair to work out the percentage figure of parasitism on the total number of host individuals or even on the number of larvae. This parasite attacks only full-grown *Chilo* larvae, and the host material collected consists of larvae of all ages. If these larvae had been allowed to complete their development in the field they would have been possibly attacked by the parasite. It appears therefore that we should really work out the percentage figure only on the number of host pupae, full and empty, present in the stalks on the collection day. These represent the true number of individuals which have positively escaped the action of the parasite in the field. Parasitism by this species was therefore 0·7 per cent. for the whole period and 2 per cent. in March, in a low country locality (Ganewatta).

The same remark applies to the two other larval parasites *Apanteles flavipes* and *Macrocentrus* sp., which occurred as 0·8 per cent. and 0·3 per cent., respectively.

(i) **Xanthopimpla stemmator,** Thunb. (fig. 1).

Ichneumon stemmator, Thunberg, Mem. Acad. Sci. St. Petersburg, **8,** 1822, p. 262; op. cit., **9,** 1824, p. 313.
Xanthopimpla thoracalis, Krieger, Sitzb. naturf. Ges. Leipzig, 1899, p. 95.
Xanthopimpla bimaculata, Cameron, J. Straits Branch R. Asiat. Soc., no. 46, 1906.
Xanthopimpla nursei, Cameron, J. Bombay Nat. Hist. Soc., **17,** 1907, p. 952 ; Morley, Hym. British India, **3,** 1913, p. 121, ♀♂.
Xanthopimpla fascialis, Szépligeti, Notes Leyden Mus., **29,** 1908, p. 256, ♂.
Xanthopimpla stemmator (Thunb.) Roman, Zool. Beitr. Uppsala, **1,** 1912, p. 280, ♂ ; Ark. f. Zool., **8,** no. 15, p. 17, ♀♂.

♂♀. Yellow with black spots arranged as follows : two small on the posterior face of the head, three on the mesonotum (two large on the lateral lobes and a smaller one, more brownish, just above the scutellum) two on the supero-lateral areas of the propodeon, one pair on the 1st abdominal tergite, fused in the middle, and one pair on each of the following tergites, those on the 7th being the largest and on the 8th (pygidium) the smallest, the latter sometimes missing as well as those on the 6th tergite.

Head with face distinctly punctate, the punctures placed about twice their diameter apart ; stemmaticum black, produced towards the space between the antennae ; flagellum of antennae brownish black, composed of 32 to 34 segments, 1st segment three times as long as large, length of second equal to twice its breadth. *Thorax* : propodeon with metapleural carinae incomplete, posterior lateral carinae of the superomedian area sometimes missing, coxal areas obsolete ; wings with second radial abscissa sinuate, recurrent nervure also sinuate, surface of wing slightly more hairy near apical margin, which is thus somewhat infuscated, stigma brownish black. Legs with fourth joint of hind tarsi about half length of third joint. *Abdomen* : first tergite smooth and shining, second punctate on the sides but smooth or with only a few punctures on the middle, third to sixth strongly punctured, seventh and eighth minutely punctured. Ovipositor (seen from above) as long as the first three abdominal tergites together, sheaths black.

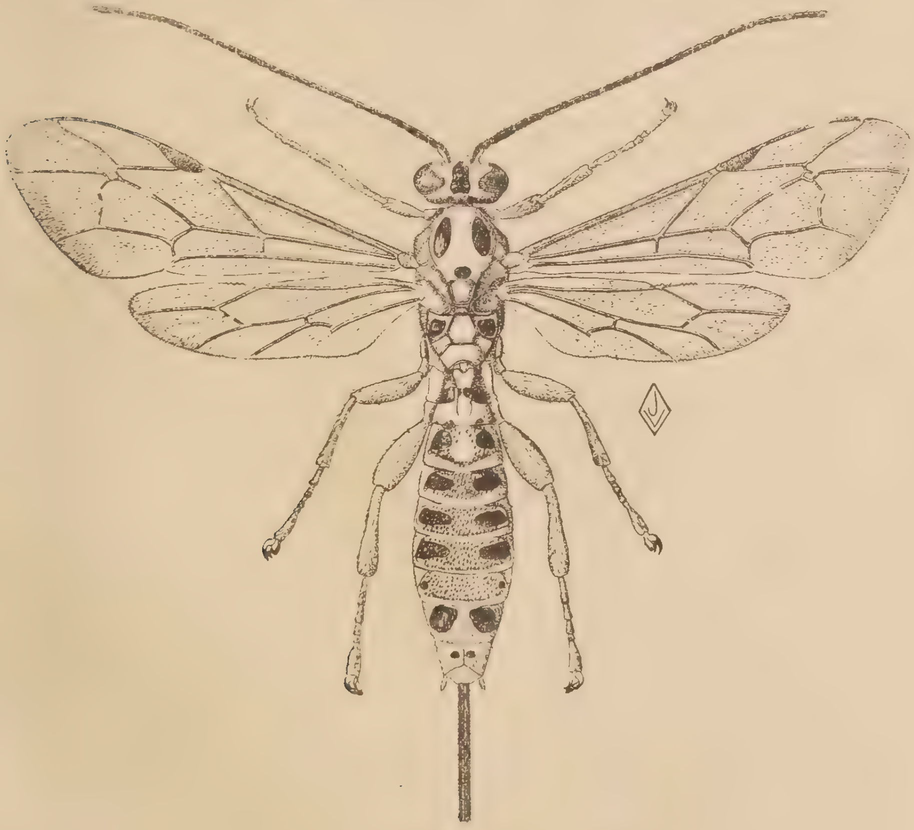

Fig. 1. *Xanthopimpla stemmator*, Thunb.

Length : ♀ 10·5+2·5 mm. (ovipositor) to 12+3 mm. ; ♂ 9 to 13 mm.

Distribution.—Farther India, Formosa, Java, Batjan, Kei Is. Found by the writer in Ceylon and introduced into Mauritius, where it seems established.

Hosts.—*Chilo zonellus* on maize and *Plusia orichalcea*, F. (India: G. R. Dutt); *Pyrausta nubilalis*, Hb., *Eucosma schistaceana*, Sn., *Chilo infuscatellus*, Sn., *Diatraea venosata*, Wlk., *Omphisa illisalis*, Wlk., *Metanastria punctata*, Wlk., *Scirpophaga nivella*, F., *Sesamia inferens*, Wlk. (Formosa: W. B. Cartwright, S. Takano and J. Sonan, cf. Rev. Appl. Ent., (A) **18,** p. 8; (A) **22,** pp. 114, 521. In Ceylon, bred from *Chilo zonellus* on maize, and in Mauritius its host is very probably *Diatraea* on sugar-cane.

Bionomics.—By means of her antennae the female wasp localises the host pupa in the stalk and reaches it by piercing the rind with her powerful ovipositor. This localisation is not always perfect, and sometimes no pupa is found at the place stung by the wasp. Even if a pupa is present, it is generally not reached at the first sting, probably on account of its immediate natural reaction of revolving quickly as soon as the sting is felt. Thus the wasp is often seen stinging repeatedly until the pupa is finally reached. The usual place of successful stinging seems to be on the wing pads of the pupa.

One egg is then laid in the host, which probably hatches after a few hours. The larva is full-grown about ten days after hatching and changes to a nymph, from which the adult will be formed a week after. The adult emerges from the host pupa by gnawing a circular hole at the anterior part so as to form a kind of operculum. The total life-cycle from egg to imago was from 16 to 19 days at Peradeniya in February and March, with an average of 17 days.

It appears that the female is ready for egg-laying from 10 to 12 days after emergence. Her longevity is from 30 to 60 days, under laboratory conditions. The life of the male was found to be somewhat shorter: 20 to 40 days.

The number of eggs that can be laid by one female has not been accurately determined but it does not appear to be very great, at least in confinement. The fact that 7 females obtained from field collected material produced offspring totalling 35 individuals, or 5 per female, may be an indication that the fecundity of the insect is rather limited. However it is almost certain that a female can lay at least 14 eggs, because on dissection it was found that the ovary is composed of seven pairs of ovarioles, each containing a mature egg. The remainder of the ovariole contained an indefinite number of egg-cells.

Laboratory Breeding.—Breeding was carried out in rectangular glass jars measuring $8\frac{1}{2} \times 4\frac{1}{2} \times 4\frac{1}{2}$ inches, with a mouth 4 inches in diameter. These jars were used in an horizontal position. The mouths were closed by a piece of organdie cloth fixed by means of a rubber band.

The *Chilo* pupae were offered to the parasite in several ways: (*a*) naked, (*b*) placed in pieces of maize stalk in holes perforated with a cork borer of suitable size, (*c*) tightly wrapped in a small piece of muslin or organdie. The parasite always ignored the naked pupae but those inserted in maize pieces or wrapped in tissue were readily accepted, and the last method was adopted.

The pupae which had been exposed to the parasite were removed from the breeding jars every day or every two days and were placed in other containers until emergence.

The adults were fed on a mixture of golden syrup and honey diluted in water; lump or granular sugar was also accepted by the wasps.

A total of 80 individuals was obtained from the seven original females emerged from field collected material.

A greater number would have probably been obtained if *Chilo* pupae had always been available. It was attempted to expose other types of pupae to the parasite, such as those of the Noctuids, *Tiracola plagiata*, Wlk., *Prodenia litura*, F., and *Sesamia inferens*, Wlk. All the pupae were accepted and oviposition observed in them, but it was only from the *Sesamia* that the parasites subsequently emerged. Pupae of this kind were unfortunately very rare. From the twenty *Tiracola* pupae exposed to the parasite only one yielded a parasite, but this specimen was abnormal—it was much too fat—and died three days after emergence. The *Prodenia* pupae were also unsuccessfully parasitised.

Finally, it was noticed that in confinement the second generation of this parasite will oviposit but very sparingly and sometimes not at all. Another curious observation was that it seems almost impossible to induce field captured females to reproduce in confinement. This, however, deserves further investigation.

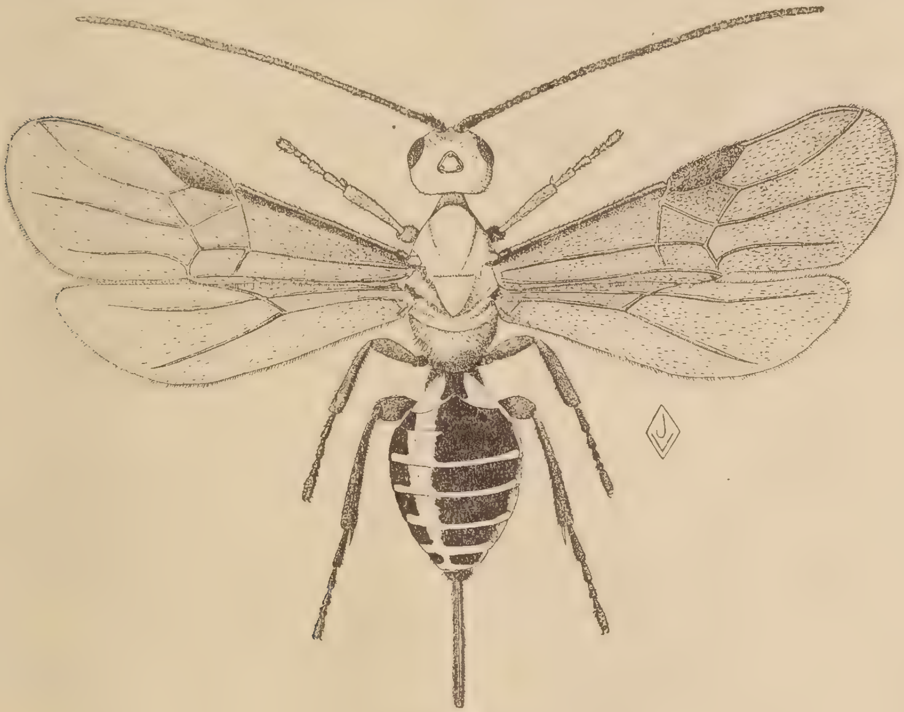

Fig. 2. *Bracon albolineatus*, Cam.

(ii) **Bracon albolineatus,** Cam. (fig. 2).

Bracon albolineatus, Cameron, Int. ent. Z., **3,** 1910, p. 278.

♀. Black and shining, with thorax and head orange-red, abdomen black with white markings more or less conspicuous, wings infuscated and iridescent, stigma brownish black.

Head a little narrower than the thorax, completely orange-red, except eyes, ocelli and tip of mandibles ; smooth and shiny, face clothed with pale yellow pubescence ; eyes small, fairly convex, stemmaticum surrounded by a furrow ; antennae brownish black, 41-jointed, joint 1 of flagellum about one-third longer than second. *Prothorax* ; mesonotum and scutellum orange-red, completely smooth and shining. Propodeon reddish brown, lighter in colour in immature examples, completely unsculptured and smooth, bearing a short yellowish-white pubescence more profuse on the sides. *Legs* : first pair orange-red, second and third pair brownish black. *Abdomen* ovoid, black ; first tergite narrow, twice as long as broad, second tergite with base cuneiform in the middle and emarginate on the sides, pleural regions of the first two abdominal segments yellowish-white, apices of 3rd to 7th tergites narrowly yellowish white, this white line being interrupted at middle in the 3rd and 4th (these white markings of the abdomen are more visible on live or fresh specimens and in such specimens the underside of the abdomen is also conspicuously white), all tergites smooth, scarcely pubescent. Ovipositor sheaths black, equal in length to tergites 2–5 together.

♂. Similar to female except the head, which is largely brownish black, the eyes proportionately larger, the second pair of legs lighter in colour, and the size distinctly smaller. Antennae with number of joints varying from 33 to 38 in the examples examined.

Length : ♀ 4·0+1·5 mm. (ovipositor) to 5·5+1·6 mm. ; ♂ 2·0 to 4·2 mm. The maximum sizes given seem to be normal ones.

Distribution.—Moluccas. In the British Museum there are examples from Southern India, Malaya and Siam. Found by the writer in Ceylon and introduced into Mauritius, but there is still no indication that it is established there.

Hosts.—Hitherto no published records. In Ceylon this species was observed as a larval parasite of *Chilo zonellus* on maize, and specimens in the British Museum bear the following host data : " ex Lepidopterous borer on Sorghum " ; " ex larva of *Sesamia inferens* " ; " ex rice stem-borer " ; " ex *Diatraea* larva."

Bionomics.—The female inserts her ovipositor through the rind of an infested stalk and stings the borer larva. The location of the host is probably not always perfect : on one occasion, at least, on cutting open the maize stalk where the stinging had been observed in the field no larva was found under the puncture, though a very small *Chilo* larva, obviously unsuitable for parasitism, could be seen in the vicinity of the sting.

The effect of the sting of *B. albolineatus* on the *Chilo* larva does not appear to be a simple paralysis as in the case of so many parasites. It seems to be a real death, the stung caterpillar becoming completely inert and typically flaccid. Such caterpillars normally keep in a fresh condition, as if the venom of the wasp has a preservative effect on them, until the parasite larvae feeding on them have completely absorbed their contents. It has been noted, however, that in the case of *Diatraea* the stung larvae occasionally show weak movements even a few days after parasitism. But the normal fate of stung caterpillars seems to be actual death.

The egg is elongate, distinctly arched, tapering gradually towards one of the ends ; it measures 1·15 mm. in length and 0·25 mm. in diameter. If it is examined immediately after oviposition a dilatation will be seen on one side, near the tapered end, but the normal shape is recovered very soon afterwards. The colour is pure white with one or both ends translucent, according to the age of the egg.

These eggs are laid externally on any part of the caterpillar, but in many cases they have been found on the thoracic segments or on the last abdominal one. They are generally found in groups varying from two to eight, and are only loosely attached to the host, apparently just by slightly adhering to the setae or to the legs of the caterpillar. Since the parasitised larva never recovers, this attachment seems quite sufficient.

The egg stage lasts about 24 hours. The hatching larvae crawl over the host body and eventually thrust their mouth-parts through the skin of their victim and feed externally. Their size increases very rapidly, and after four days they are full-grown, measuring 7 mm. in length. They leave the empty skin of their host and start spinning their cocoon within the borer tunnel.

The adult emerges from the cocoon after 10 to 12 days. The complete life-cycle therefore occupies 15–17 days at a temperature varying between 25·5 and 30°C., with an average of 27°C. This is the temperature recorded in the laboratory where this parasite was being reared in Ceylon (Peradeniya) in 1939.

Mating occurs a few hours after emergence, and the female is ready for oviposition one to three days afterwards. The female can live from 30 to 32 days in confinement, but very often the longevity is not so long and many die after a week, or even quicker. The cause of this variation is unknown, but it appears that the longevity gradually decreases with the number of generations bred in captivity. A life of 15 days is considered as being a fairly satisfactory mean. The life of the male is shorter, a maximum of 15 days having been observed. A progeny of about 50 individuals will be produced by one female if she lives the normal 30–32 days.

The imagines of this species were often observed in maize fields, and on one occasion in a rice field. They are usually found singly, only one or two being seen at a time in the various fields inspected. However at Ganewatta, a locality of the North Western Province, a total of 42 individuals (14♀♀ and 28♂♂) was captured over a period of three days (10th–12th March 1939) in a field of five acres of maize. These wasps were taken chiefly on leaves of castor oil plants adjoining the maize field, only a few being captured on the maize. They fly chiefly from 8 to 10 a.m. but were also observed in smaller numbers in the afternoon, from 5 to 6.30 p.m. Their flight is rather slow and they are easily captured by means of a butterfly net. Taking them directly on foliage with a glass tube is also possible, but is by no means an easy task. Mating has been repeatedly observed in the glass tubes immediately after collection, and also in the breeding jars.

Laboratory Breeding.—The following technique was used for rearing *B. albolineatus* in Ceylon: the adults were kept in rectangular glass jars (fig. 3) placed in a horizontal position. The size of the jars was $8\frac{1}{2} \times 4\frac{1}{2} \times 4\frac{1}{2}$ inches, with a mouth 4 inches in diameter. It is not advisable to use smaller ones, as it is essential for the hand to move freely inside.

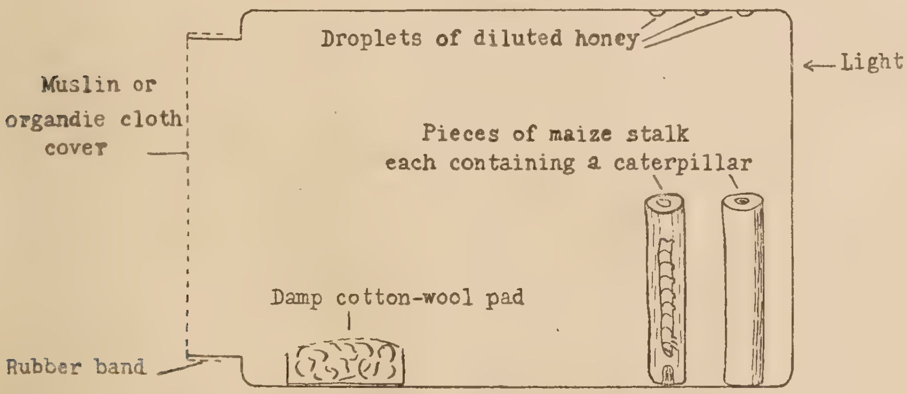
Droplets of diluted honey
Light
Muslin or organdie cloth cover
Pieces of maize stalk each containing a caterpillar
Damp cotton-wool pad
Rubber band

Fig. 3. Glass jar for breeding *Bracon albolineatus*.

The mouth of the jar is closed by a piece of organdie cloth fixed with a rubber band. The food used was a mixture of honey and golden syrup diluted in water. Some drops are applied daily with a brush on the " ceiling " of the jar. Raisins were not at all appreciated, but lump or granular sugar was sometimes taken. These parasites do not appear to take much food during their life-time, except just after emergence when they will feed greedily on the syrup.

In dry weather moisture is provided by a damp cottonwool pad, and the cloth shutting the opening of the jar is also moistened daily. In damp weather this procedure is not necessary, and may be even detrimental, as excessive moisture will gather on the sides of the glass.

The caterpillars to be parasitised are placed in small pieces of maize stalk about 1½ inches long. A hole is bored in them from end to end by means of a cork borer about one-fifth inch diameter. One end is plugged with cottonwool, the larva is introduced into the cavity and the other end is lightly plugged with pith. Before exposing these pieces to the parasite their rind is removed with a scalpel and their diameter reduced as much as possible (to about ½ or 2/5 inch) to facilitate parasitism. These pieces are then placed vertically near the bottom end of the jar, this bottom facing daylight.

The wasps being strongly phototropic are not liable to escape during the various manipulations. Every day or every two days these maize pieces are examined and those containing parasitised caterpillars are removed and placed in glass tubes plugged with cottonwool, which are kept horizontally on a suitable rack. Parasitised caterpillars being motionless and flaccid are easily recognised. The cocoons are spun into the maize pieces or between them and the glass of the tube.

From the 20th February to the 10th June, *i.e.* a period of 110 days, a total of 1,408 adults had been obtained from the 23 females collected in the field (1 captured on 20.ii, 14 on 10.iii, 1 on 21.iii, and 7 hatched in the laboratory from field-collected material). It is believed that a higher production would have been reached if host material had always been available. But the *Chilo* larvae became more and more scarce from the end of March, and the supply reached its very end by the middle of May.

Experimental Hosts.—In June, when the supply of *Chilo* larvae had come to an end, it was attempted to rear the parasite on other hosts that could be obtained easily. The larvae of three free-living Noctuids, *Spodoptera mauritia*, Bdv., *Prodenia litura*, F., and *Tiracola plagiata*, Wlk., were utilised. They were imprisoned in small pieces of maize pith, as for *Chilo*, and exposed to the parasite. Several of the *Prodenia* and *Tiracola* larvae made their way out of the pith, others remained inside but were not parasitised, whilst of the six *Spodoptera* larvae included three were actually parasitised. However the development of the parasite larva on them was not at all satisfactory, only one or two reaching the cocoon stage. It was thus obvious that *Spodoptera* was fairly attractive to the wasp for egg-laying, and if the eggs could be transferred successfully on to a better host the problem would be solved. The writer remembered that Dr. W. R. Thompson transferred successfully the eggs of *Exeristes roborator*, an Ichneumonid parasite of the European Corn Borer, on the larvae of a large ant. It was attempted to apply this idea to the Ceylon parasite. Eggs laid on *Spodoptera* were removed and placed on the larvae of a large arboreal ant very common in Ceylon (*Oecophylla smaragdina*). The hatching parasite larvae fed on the defenceless prey, but the number reaching the cocoon stage was so small as to be insignificant for the practical purpose aimed at. The size of the artificial host was apparently too small, otherwise the process would have probably worked fairly well.

Effect of Cold Storage.—Owing to the lack of frequent boat communication between Ceylon and Mauritius, retardation of the emergence of this parasite by cold storage had to be resorted to. A certain number of experiments were made at Peradeniya in a refrigerator cooled to 40–45°F. (4·5–7·2°C.). The results obtained are shown in the following table.

Age of cocoon (days)	Number of days kept in refrigerator (40–45°F.)	Number of days between removal from cold and emergence	Percentage of emergence
7	2	2	83
7	10	5–10	70
5	4	9–10	100
4	13	5–7	100
3	5	7	90
3	22	3–4	62
2	35	7	86
1	5	9	100
Fresh	4	13	100

From the above table it may be seen that *B. albolineatus* undergoes cold storage fairly well. It has not been possible to test exactly the fertility of adults emerging from refrigerated cocoons, but if it is impaired it is probably in a slight proportion only.

By refrigeration the length of the cocoon stage, which normally lasts 10–12 days, can thus be greatly extended. This is of great help when it is necessary to wait for host material or to effect timely shipments of the parasite. For instance, when by mid May 1939, *Chilo* larvae were no longer available in Ceylon for the rearing of this parasite, most of the cocoons in hand were placed in a refrigerator to wait for a direct ship for Mauritius. They were removed on the 10th June and shipped on that day. They had thus been kept in the cold for 10 to 35 days. Nearly all of them emerged during the voyage, which lasted nine days, and the adults reached Mauritius in quite satisfactory condition.

The above results also show the possibility of shipping the cocoons in cold storage in case of a longer voyage, in vessels provided with proper refrigeration.

(iii) **Apanteles flavipes,** Cam.

Cotesia flavipes, Cameron, Mem. Proc. Manch. Phil. Soc., (4) **4,** 1891, p. 185.

Apanteles nonagriae, Oliff, Agric. Gaz. N. S. Wales, **4,** 1893, p. 381 ; Wilkinson, Bull. Ent. Res., **19,** 1928, p. 136.

Apanteles (*Stenopleura*) *nonagriae*, Viereck, Proc. U. S. Nat. Mus., **44,** 1913, p. 645.

Apanteles (*Stenopleura*) *simplicis*, Viereck, *l.c.*, 1913 ; de Charmoy, Bull. no. 5, Sci. Ser., Dep. Agric. Mauritius, 1917, p. 28.

Apanteles flavipes (Cameron) Wilkinson, Bull. Ent. Res., **19,** 1928, p. 93 ; *ibid.*, **20,** 1929, p. 108.

The following is a redescription made by Wilkinson (1928, *l.c.*) from Cameron's unique type (Poona, India), from several examples from Pusa and from one female co-type each of *A. nonagriae* and *A. simplicis*, both from Taihoku, Formosa. The above synonymy is also given *fide* Wilkinson.

"♀♂. Black ; legs, antennae, mouth parts, and basal ventrites red testaceous ; stigma and wing veins mostly brown ; tegulae and costal vein testaceous ; tergites (except basal two) commonly very dark red-black.

♀♂. *Head* largely impunctate, smooth, polished, and shining ; face weakly but definitely punctate (degree 1–2) ; antennae of females submoniliform, short, not as long as body, of males normal, longer than body. *Thorax* compressed, wider between tegulae than deep dorso-ventrally ; mesonotum with strong, unusually well separated, and comparatively sparse punctuation (degree 3–4), more densely punctate anteriorly ; otherwise mesonotum absolutely smooth, polished and shining, as are the disc of the scutellum, and the mesopleurae, except that the latter have a few punctures anteriorly (degree 3) ; propodeon evenly rugulose. *Wings* : length of the transverse cubital and of the recurrent each about equal to the breadth of the stigma, and definitely longer than the 1st abscissa of the radial, which is about equal to the apical portion of the 1st abscissa of the cubital, which latter is a little shorter than the pigmented portion of the 2nd abscissa of the cubital ; stigma shorter than metacarp. *Legs* : hind coxae at least at base above with well separated punctures (degree 3–4) ; hind tibial spurs sub-equal, hardly half as long as the basal joint of the hind tarsus. *Abdomen* : 1st and 2nd tergites longitudinally rugulose, succeeding tergites smooth, polished, shining and impunctate ; ovipositor sheaths short.

Length, 2–2·5 mm."

Distribution.—India, Ceylon, Formosa, New South Wales, Mauritius.

Hosts.—*Chilo zonellus* on *Sorghum vulgare* and maize in India and Ceylon ; *Chilo supressalis*, Wlk. (=*simplex*, Butl.) and *Sesamia inferens*, Wlk., in Formosa ; *Phragmatiphila truncata*, Wlk. (Noctuid) in Queensland ; *Diatraea mauriciella*, Wlk., in Mauritius.

Bionomics.—Like the other member of the genus, *Apanteles flavipes* is an internal parasite of caterpillars. As many as 60 to 75 larvae may be found infesting a single caterpillar, but the normal figure is about 20–25. When they are full-grown these larvae come out by piercing their host's skin and rapidly spin their cocoons on it or in its immediate vicinity. These cocoons are pure white in colour and form a very conspicuous mass.

An attempt was made to study in detail the bionomics of this species in Ceylon, but unsuccessfully. The adults generally died after six or seven days, apparently without taking any notice of the *Chilo* larvae exposed to them. As this species already existed in Mauritius on *Diatraea* and therefore presented no particular interest to the scheme in view, no more attention was devoted to it in Ceylon.

In Mauritius de Charmoy (1917) recorded a life-cycle of 15–20 days. It is curious to note than in Formosa *A. flavipes* was bred from *Sesamia* and in Queensland from *Phragmatiphila truncata*, another Noctuid, whereas in Mauritius it seems to be exclusively a parasite of *Diatraea*.

(iv) **Macrocentrus** sp.

♂. Reddish brown, shiny with the last three abdominal segments brownish black and the 2nd tergite infuscated.

Head : face light brown ; antennae 55-jointed, flagellum brownish black. *Thorax* brownish testaceous. Legs yellowish red with the hind femorae darkened at apex, the tibiae darkened except at base and the tarsi partly darkened ; trochanters dentate, the hind pair with about seven teeth. Wings hyaline, slightly infuscated, with stigma brownish black. *Abdomen* thin, practically of uniform breadth throughout. All tergites smooth, except second very feebly aciculated, 1st tergite with spiracles protruding at the sides (dentiform).

Length, 10 mm.

♀. Unknown.

Distribution.—Ceylon.

Host.—*Chilo zonellus* on maize.

Bionomics.—A larval parasite. Only three males were obtained from *Chilo* material collected at Mailapitiya and Teldeniya at the end of January and beginning of February 1939. The bionomics could not therefore be studied. The cocoon measures $12 \times 3{\cdot}5$ mm. ; it is reddish brown, darkened towards the posterior end, practically without silky threads. It is formed in the host's tunnel.

8. The Shipment of Borer Parasites to Mauritius, their Rearing, Liberation and Establishment.

The great difficulty with which the writer had to contend for the forwarding of the parasites was the erratic steamer communication between Ceylon and Mauritius, there being no fixed sailing schedule. For instance, from 10th April to 10th June there was no direct sailing at all, and many parasites would have been available for shipment during that period, whereas in July, when the work was completed and the writer left Ceylon, three or four steamers left Colombo for Mauritius.

Of the parasites mentioned in the preceding pages two were shipped for Mauritius : the Ichneumonid, *Xanthopimpla stemmator*, Thunb., and the Braconid, *Bracon albolineatus*, Cam. In addition, another parasite likely to be useful against *Diatraea* was introduced simultaneously from Ceylon. It is the egg-parasite *Trichogramma evanescens*, Westw., which will be bred in mass and tried against *Diatraea*.

Xanthopimpla stemmator, Thunb.

Shipment.—The shipments were made in cases or crates (fig. 4) consisting of two 4-gallon petrol tins soldered together, over which a wooden frame 13 inches high, covered with black calico, was carefully fitted. The cloth was protected from being damaged by 20-mesh wire gauze stretched exteriorly on the sides and top. The dimensions of the cases were: total height 28 inches, length 18½ inches, width 9½ inches. They were equipped as follows: At the bottom of each of the two tins was placed a ½ inch layer of damp sphagnum moss. Over this a 2–3 inches layer of moist sandy loam, then another layer of moist sphagnum about 1 inch thick, and the whole pressed in position by means of a piece of ½ inch mesh wire netting.

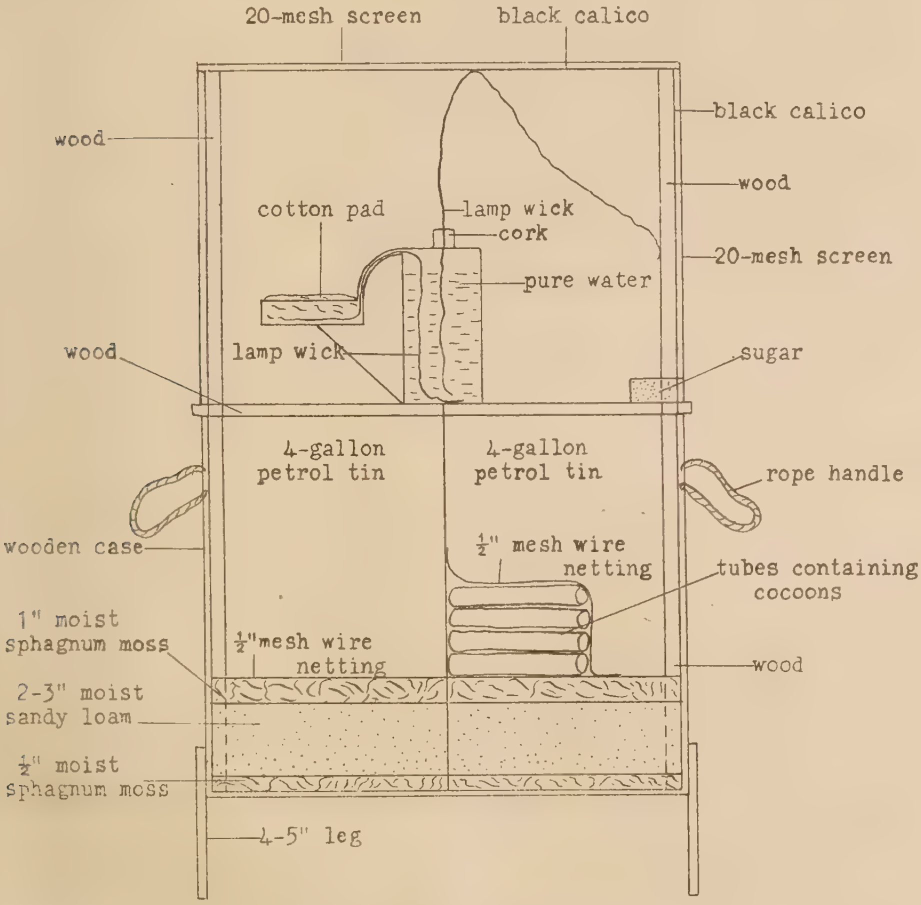

Fig. 4. Section of case used for shipping borer parasites from Ceylon to Mauritius.

Water was supplied to the parasites by a small tin apparatus, locally made, consisting of a reservoir 6 inches high, 3 inches wide and 3 inches long. A curved flat pipe, ⅝ inch wide containing a lamp wick, fitted to the top side of the reservoir conducted the water by capillarity to a cotton pad covered with organdie cloth placed in a side tin container of 4 × 2½ inches. This side container is arranged so that its top is placed about 2 inches below the top of the reservoir and 1½ inches distant from it. The whole apparatus was nailed on the top, between the two tins. Various simple devices were applied to facilitate the access of the parasites to the pad container.

Food was provided in the form of granulated sugar placed in a long rectangular tin cup (7×2×1½ inches) nailed at one end of the case. Threaded raisins were also hung in the cage.

A few lengths of crêpe paper were stretched in all the cases to furnish a foothold for the wasps and prevent unnecessary flying.

When everything was thus prepared the case was closed up by fitting the top piece of black cloth and wire gauze, and the adult parasites were introduced through an inch hole punched on the side of one of the tins which was finally soldered.

For the voyage, the bottom part or tin portion of the cases was placed in a wooden container provided with rope handles and four legs 5 inches long, upon which a tree-banding grease was spread to prevent any possible ant invasion on board.

Two shipments of laboratory bred material were made. The first one left Ceylon on the 10th April 1939, and reached Mauritius after 11 days (21st April). It consisted of 18 males and 19 females which were all received alive.

The second shipment was made on the 10th June and arrived in Mauritius on the 19th, *i.e.* 9 days voyage. It was very small, consisting only of 9 males, 5 females (emerged since a fairly long time) and 7 parasitised *Chilo* pupae. From these 21 individuals, 7 males and 3 females, or 47·6 per cent., were received alive.

Breeding and Liberation.—The breeding of this species on *Diatraea* pupae could not be attempted owing to the fact that none were available at the time of reception. A few pupae of the Noctuids *Sesamia vuteria*, Stoll, and *Simplicia inarcualis*, Gn., were exposed to 6 females and 2 males taken from the material received on the 21st April. Of these, only one pupa of *Sesamia* was successfully parasitised.

The remaining 16 males and 13 females were immediately released in the north of Mauritius, in a locality severely infested with *Diatraea.*

Of the second shipment, it is reported that the 3 females that reached Mauritius safely were devoured by ants the day after their arrival and so no rearing and no liberation was made from that consignment.

Establishment in Mauritius.—When the writer sent this parasite to Mauritius he was somewhat sceptical that it would adapt itself to *Diatraea mauriciella.* It was feared that this species of *Xanthopimpla* was possibly restricted to Lepidopterous pupae enclosed in stalks, as in the case of *Chilo zonellus,* and would not be able to attack those of the Mauritius *Diatraea,* generally well concealed in trash and dry leaf-sheaths.

However, on the 15th September 1939, *i.e.* five months after the small single release of 13 females, several individuals were recovered in the *Diatraea*-infested zone of liberation. By that time the specific determination of the parasite had been secured from the Imperial Institute of Entomology and by looking through the literature it was found that this *Xanthopimpla* was recorded as a parasite of *Diatraea venosata* in Formosa.

In May and June of the following year (1940) the parasite had greatly spread in Mauritius and was observed in numbers three miles from the original centre of liberation, in a region densely infested with *Diatraea* (Belle Vue Harel Estate). It would have then been possible to capture over 100 adults a day.

From May to September 1940, 1,571 individuals were captured in that same place and distributed all over the island on 38 *Diatraea*-infested estates. The method used to capture these wasps in the field is simple : Sugar solution is sprayed on the foliage of a few rows of sugar-cane and after a few minutes, if the weather is favourable, the parasites come to feed on the syrup. They are then easily captured with a net.

This observation suggests at the same time that there may be a lack of proper food plants for the wasp in Mauritius cane-fields. The ordinary melliferous plants appreciated by the Scoliid parasites of *Phytalus* (*Cordia*, *Stachytarpheta*, *Eupatorium* etc.) do not seem to be suitable for *Xanthopimpla*.

Bracon albolineatus, Cam.

Shipment.—The shipments to Mauritius were made in the same type of case as for *Xanthopimpla*. But as both adults and cocoons were shipped, the latter were placed in tubes very lightly plugged with wood wool. These tubes were piled up at the bottom of one of the tins so as to allow the free emergence of the adults during the voyage ; a piece of ½ inch mesh wire netting was used to keep the tubes in the desired position.

Referring to the refrigeration experiments with this parasite, it may be seen that shipping the cocoons in cool storage to Mauritius would have been probably a quite satisfactory method. Unfortunately the direct service between Colombo and Mauritius was done only by cargo boats which were not generally equipped with proper refrigerators.

Two shipments of laboratory-bred material were also made, simultaneously with the *Xanthopimpla* ones, *i.e.* on the 10th April and 10th June, 1939.

The first one consisted of 56 males, 56 females and 352 cocoons. It reached Mauritius after 11 days voyage and from this total of 464 individuals only 28 were received alive (9 males and 19 females) or 6 per cent. All the adults had emerged from the cocoons during the voyage.

The second consignment consisted of 81 males, 47 females and 167 cocoons. The voyage lasted 9 days and 172 parasites, or 58 per cent., were received alive. Most of the insects emerged from the cocoons during the voyage, except a few which emerged one day after arrival.

It is surprising to note that the mortality was so much higher in the first shipment which was composed of freshly emerged adults and of freshly formed cocoons. Whereas the adults of the second shipment had already spent several days in confinement, and a large proportion of the cocoons had been refrigerated from 10 to 35 days prior to shipment. Just the opposite results might have been forecast. The length of the voyage two days longer in the first cannot certainly account for the difference. The same type of shipping container provided with the same food and the same amount of moisture was used in both cases. It is reported, however, that the water supply apparatus of the first consignment arrived in Mauritius completely dry, but that it still contained plenty of water in the second. This detail would quite possibly indicate that too much sunlight reached the first consignment during the voyage, causing a rapid evaporation of the water and at the same time killing a large proportion of the insects.

Breeding and Liberation.—16 out of the 28 adults received alive in the first shipment and 14 of the 172 adults of the second shipment were kept in the laboratory for breeding. The remainder, *i.e.* 12 and 158, respectively, were immediately released in cane-fields highly infested by *Diatraea*.

In Mauritius the breeding was carried on with *Diatraea* and *Sesamia* larvae on approximately the same lines as in Ceylon. Instead of maize pith for enclosing the larvae to be parasitised, young sugar-cane shoots, still unfolded, were used. The breeding jars measured 14×8×4 inches and contained a tin rack perforated with 36 holes ½ inch diameter to hold the small cane pieces vertically.

At the end of May, with the advent of the cold weather (temperature frequently falling to 53·6°F. (12°C.) at night, with an average of 68°F. (20°C.) at Reduit) it is reported that the parasite became somewhat inactive, and it was found necessary to rear it in a cabinet electrically heated between 77 and 93°F. (25–34°C.). Subsequently, with the acquisition of a thermostat, the temperature was maintained constant at 29°C. in that cabinet. Under such conditions the parasite developed satisfactorily and a generation was obtained every eleven days. The use of constant temperature was maintained even during the hot season.

The breeding was done with an original stock of 20 females taken from the two shipments received from Ceylon. The first breeding was commenced on the 21st April 1939, with 10 females and 6 males and the second one on the 19th June with 10 females and 4 males.

After a period of 109 days (27.iv to 14.viii) 756 adult parasites had been reared in Mauritius, which represents only half the quantity obtained in Ceylon during an equivalent period of time and starting with about the same number of original females (1,408 adults were obtained after 110 days, starting with 23 females).

It is true that in Ceylon a much better emergence was obtained from the cocoons, practically 100 per cent. of them producing imagines, whereas in Mauritius it was only 61 per cent., on the average. This may be due to the fact that in Ceylon the cocoons were less handled. The parasitised material being contained in maize pith, excessive moisture and mould never developed in the tubes where it had been placed, and it was therefore not necessary to disturb the cocoons until emergence. In Mauritius much moisture was often produced by the sugar-cane shoots used, and the cocoons had to be pulled from them to be transferred elsewhere.

The breeding progressed fairly satisfactorily up to January 1940, when an element of failure introduced itself in the work : the emerging adults died after 1–3 days (instead of the normal 8–30 days), without achieving parasitism in most cases. It will be noticed that no liberations have been made since that time, the few parasites saved being reserved for laboratory breeding with the hope of rebuilding a healthy strain. But the breeding decreased steadily, and in April 1940, *i.e.* just one year after its introduction into Mauritius, the stock of parasites finally died out in spite of all efforts.

The reason of this premature death of the adults remains obscure. But it is possible that it was caused by a degeneration of the strain due either to numerous in-breedings or to the rearing on host larvae of unsuitable size or age.

The following table shows the number of cocoons obtained in Mauritius, the number of adults emerged from them and the number of adults released in the fields.

Period of cocoon formation	No. of cocoons	No. of adults emerged			Number of adults released		
		Males	Females	Total	Males	Females	Total
27.4 to 8.5.39 ...	172	72	65	137	49	40	89
16.5 ,, 7.6.39 ...	351	85	96	181	70	81	151
9.6 ,, 12.7.39 ...	263	77	82	159	54	69	123
13.7 ,, 14.8.39 ...	349	167	112	279	34	13	47
16.8 ,, 30.9.39 ...	577	155	127	282	12	12	24
2.10 ,, 3.11.39 ...	882	377	212	589	208	159	367
6.11 ,, 5.12.39 ...	3,001	997	558	1,555	681	403	1,084
6.12 ,, 3.1.40 ...	1,225	584	425	1,009	475	298	773
6.1 ,, 12.2.40 ...	829	267	245	512	0	0	0
14.2 ,, 28.3.40 ...	266	104	48	152	0	0	0
6.4 ,, 19.4.40 ...	12	7	3	10	0	0	0
TOTALS ...	7,927	2,892	1,973	4,865	1,583	1,075	2,658

Together with the 170 adults taken from the material received from Ceylon, the total number of *Bracon albolineatus* released in Mauritius is therefore 2,828.

Prospects of Establishment in Mauritius.—In view of the close affinities existing between *Chilo* and *Diatraea* and the ease with which *B. albolineatus* accepted *Diatraea* larvae in Mauritius, great hopes were entertained as to its establishment in this Island. These hopes were reinforced when it was subsequently learnt from the Imperial Institute of Entomology that some of the examples of this species in the British Museum, from Southern India, Malaya and Siam, had been bred from *Diatraea* and *Sesamia* (the host-plant is not stated but other specimens are labelled " ex Lepidopterous borer on Sorghum " and " ex rice stem-borer ").

However, two years have elapsed since this parasite was released for the first time in Mauritius and there has been no recovery in the field. It is to be feared that it has not established itself here, in spite of the fairly large number of individuals liberated in various localities during nine months. This possible failure may be due to several causes.

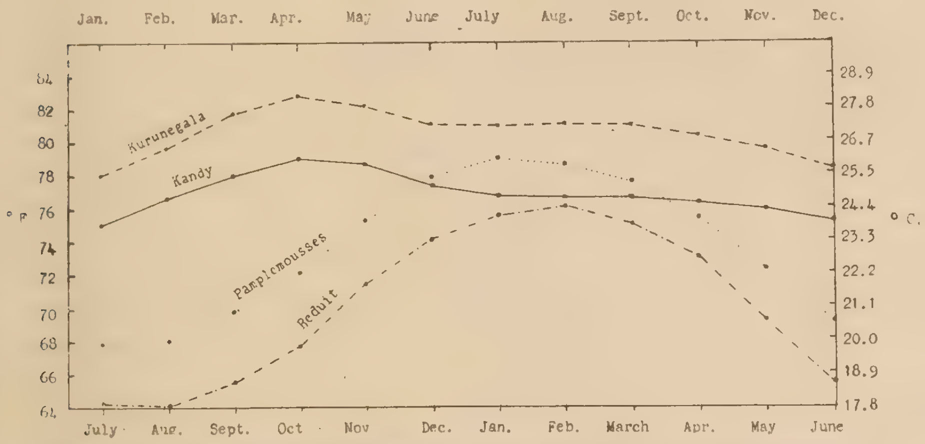

Fig. 5. Mean monthly temperatures at Kurunegala and Kandy (Ceylon) and at Pamplemousses and Reduit (Mauritius). The curves for Ceylon are from January to December, those for Mauritius from July to June.

Climatic differences between Ceylon and Mauritius may have interfered to some extent. If, as shown by the curves of temperature given (fig. 5), some of the localities where this parasite was observed in Ceylon are not much hotter than the northern part of Mauritius, the average yearly temperature is decidedly higher in any of these Ceylon localities. For instance, at Kandy (1,654 feet) in the vicinity of which the parasite was observed in Ceylon, the average monthly temperature does not rise above 79°F. (26°C.), like at Pamplemousses where the insect was mainly released in Mauritius. It may be seen, however, that the average yearly temperature is somewhat higher in Kandy : 76°F. (24·4°C.) instead of 73·4°F. (23°C.) at Pamplemousses. Similarly, the temperature variation between the different parts of the year is much smaller in Ceylon. At Kandy, for instance, the variation is only of about 4°F., whereas at Pamplemousses it is 11°F. In fact this smallness of temperature variation is a noteworthy feature of the Ceylon climate. Kurunegala, in the low-country zone (less than 500 feet above sea-level) may be taken as representing approximately the climate of Ganewatta, another place where *B. albolineatus* was observed in numbers in Ceylon. There the temperature is still higher than at Kandy the average yearly figure being 80°F. (26·7°C.), but it may be seen that the temperature curve is of the same type as for Kandy, *i.e.* characterised by the smallness of variation.

However, in spite of these differences in temperature it seems doubtful that the climate of Mauritius would have completely prevented the establishment of this parasite there ; it has been shown that even very low temperature will not kill any stage of this insect.

The distribution of rain is also different in Ceylon, where there are two rainy seasons, one from April to June caused by the south-west monsoon, the other from October to January, which is initiated by the north-east monsoon. In Mauritius there is only one rainy season, from December to April (fig. 6).

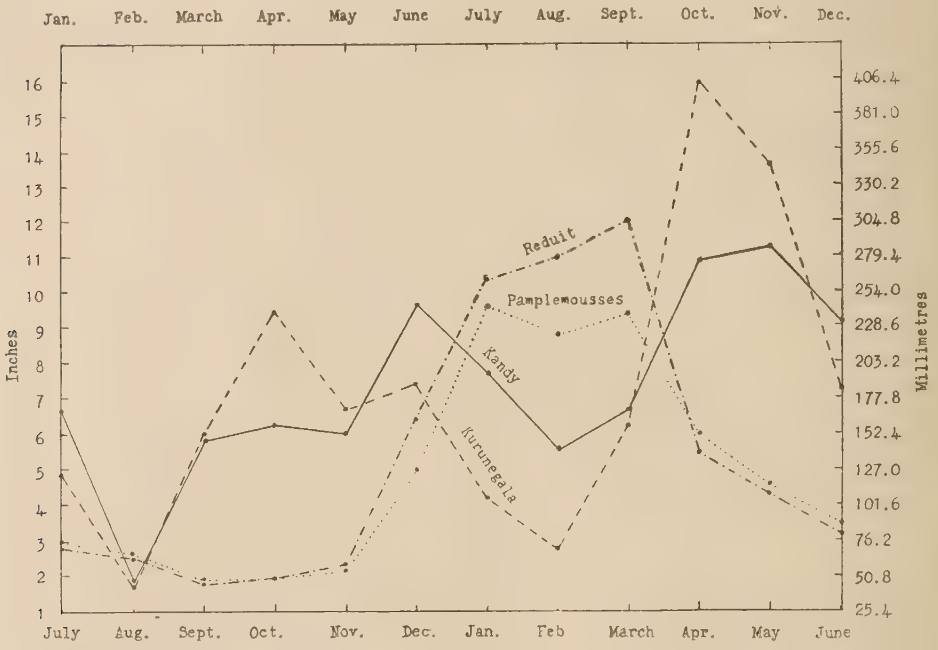

Fig. 6. Mean monthly rainfall at Kurunegala and Kandy (Ceylon) and at Pamplemousses and Reduit (Mauritius). Curves for Ceylon from January to December, for Mauritius from July to June.

The writer believes that it is rather the nature of the plant harbouring the host larva that has interfered with the establishment of this insect here. As has been already said , cocoons or even larvae could not be left in sugar-cane shoots for breeding because they would have been destroyed by the excessive moisture and mould resulting from the decaying of these shoots. It will be remembered that in nature the cocoons appear to be always spun in the burrow of the host larva. In the case of maize or sorghum, especially the mature stalks, the pith does not decay easily, thus not affecting the cocoons.

It is also probable that the ovipositor of the female wasp is too short to reach the *Diatraea* larvae situated near the central part of sugar-cane stalks. But this factor would have decreased the efficiency of the parasite and not completely prevented its establishment. Quite a number of larvae are found in young sugar-cane shoots, generally smaller in diameter than maize stalks, and others burrow sufficiently near the rind to be reached by the sting of the wasp. At any rate the parasite should have adapted itself at least to *Sesamia*, which, as a rule, lives in young cane shoots of easy access to the female wasp.

It appears, therefore, that the failure is probably due to the suspected impossibility of the cocoons being spun or preserved until emergence in the borer tunnels in sugar-cane.

Another factor that may possibly have interfered with the establishment of this parasite in Mauritius is the abundance of diurnal spiders of the genus *Salticus* in cane-fields. They are active predators of all insects of suitable size which venture on cane plants. *Bracon albolineatus* may have been an easy prey for them.

Trichogramma evanescens, Westw.

A colony of this parasite was obtained from the Tea Research Institute of Ceylon, where it was previously experimented with, without success, against the Tea Tortrix. It is a dark species imported from Europe. The nomenclature of the genus *Trichogramma* is still in a state of confusion and there is some doubt about the correct name to be ascribed to the species in question. According to Flanders (1937) *Trichogramma minutum*, Riley, should be called *T. evanescens*, Westw., whilst the species hitherto known under this name, which is probably the one under consideration here, should be known as *T. semblidis*, Aur. However, Salt (1937) considers that *Trichogramma evanescens* and *Trichogramma semblidis* are two distinct European species. The antenna of the male in the species obtained from the Tea Research Institute of Ceylon (fig. 7) seems to agree well with the species figured by him as *Trichogramma evanescens* and not with what he calls *Trichogramma semblidis*.

About 15,000 parasitised eggs were supplied in three lots of 5,000. They were taken to Mauritius by the writer when he left Ceylon on the 5th July 1939. The programme planned with the Entomologist of the Tea Research Institute for the journey of the parasite was consistently upset by the fact that the ship left Mauritius after a delay of five days.

The parcel of parasitised eggs was sent by rail from St. Coombs and reached the writer in Colombo on the 4th July. Lot no. 1 had been refrigerated for nine days at the Tea Research Institute (41–46°F.). For that reason it could not be refrigerated again (two refrigerations mean a very poor or nil emergence) and was kept at air temperature. The adults emerged during the voyage, on the 8th July.

Lot no. 2 had gone through about half the developmental cycle when received. It was immediately placed in the refrigerator of the Grand Oriental Hotel and on the day of the departure of the ship, *i.e.* the following day, it was transferred to the cold chamber of the steamer. To avoid any break in the refrigeration period a refrigerator valise, as devised by the Entomologists of the U.S. Department of Agriculture, was used for the various transfers. This lot remained in good condition until the arrival in Mauritius on the 17th July and was placed in a refrigerator at the Department of Agriculture. It yielded a fairly good emergence when required a few days afterwards.

Lot no. 3 had its developmental cycle nine-tenths completed when received. It was subjected to the same treatment as lot no. 2, *i.e.* placed in a refrigerator and subsequently in the ice chamber of the ship, but in spite of that it hatched during the voyage, on the 13th July.

The *Trichogramma* emerging on board from lots nos. 1 and 3 were placed in contact with *Prodenia litura* eggs produced daily by moths that the writer had brought from Peradeniya and also with *Ephestia cautella* eggs obtained from moths collected in the ship, which was carrying a consignment of rice for Mauritius. The *Prodenia* eggs were found to be quite unsatisfactory for the purpose ; they shrivelled quickly and eventually produced only a very small number of *Trichogramma*. The *Ephestia* ones were perfect, but unfortunately they were discovered too late and a small number only could be exposed to the parasites.

The small lots of eggs thus parasitised during the voyage, nearly daily since the 8th July, were partly placed in the ice chamber of the ship, partly kept at air temperature. They hatched in due time in Mauritius.

From the preceding lines it will be realised that the transport of *Trichogramma* from a distant country to Mauritius is not an easy procedure unless accompanied by somebody who can breed them during the voyage. The main difficulties are : (1) the short cycle of the parasite, not more than 7 or 8 days in ordinary tropical conditions ; (2) the short life of the adult under such conditions, about 3–4 days ; (3) the inability of parasitised eggs to undergo more than one refrigeration period ; (4) their inability to undergo a long refrigeration period, three weeks being the maximum possible ; (5) the general unreliability of sailing dates to Mauritius ; (6) the absence of proper refrigerators on board the cargo ships sailing between Colombo and Mauritius.

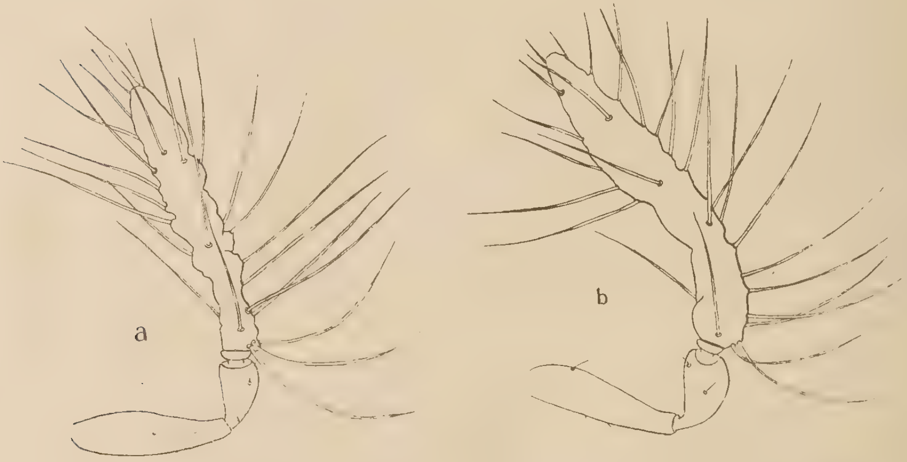

Fig. 7. *Trichogramma evanescens*, Westw., antennae of male : *a*, from stock imported from Ceylon ; *b*, from 50th generation reared in Mauritius.

The small stock that reached Mauritius on the 17th July 1939 had to be maintained for a period of 16 months (up to October–November 1940) until the unit for the mass breeding of *Sitotroga* was ready and eggs were available from it. This preliminary upkeep of the parasite was at times rather laborious. Without the acquisition of an electric refrigerator, which was used to store the host eggs, parasitised and unparasitised, so as to synchronize the emergence of the parasite with the supply of eggs, the work would have been impossible.

For the preliminary breeding of the parasite a small supply of eggs was obtained from moths of various kinds collected in an ultra-violet light trap. In these collections *Crambus seychellellus*, Fletcher, was the dominant species, and its eggs were fairly well accepted by *Trichogramma*. But this source of supply was not always reliable, windy or rainy weather and moonlight nights very often interfering.

At the close of the 1940 hot season (March–April) the writer fortuitously detected the presence of fair numbers of the moth *Corcyra cephalonica*, Staint., in a dairy foodstore. But this stock was available for a few weeks only, the advent of the cool season reducing the breeding of this insect to a very low figure. *Ephestia cautella*, Wlk., and *Sitotroga* bred in a few glass jars yielded also a small quantity of eggs.

9. Summary.

1. The Moth Borer, *Diatraea mauriciella*, Wlk., is a serious pest of sugar-cane in Mauritius. At the end of 1938 a grant was obtained from the Colonial Development Fund to enable searches to be made for natural enemies of the pest in certain foreign countries.

Ceylon was selected in the first instance, mainly on the assumption that the insect in question was accidentally introduced from that country in 1848. However, the species obtained by the writer on sugar-cane in Ceylon was found to be *Diatraea venosata*, Wlk., a species positively distinct from the Mauritian one but hitherto confused with it. The investigations in Ceylon covered a period of about six months, from January to June 1939.

2. The area found planted in sugar-cane in Ceylon was very small : about 150–200 acres, of which 100–125 were in the Galle District, 50–75 near Haldumulla, and a few small fields in other regions.

3. An extensive survey carried out in these areas revealed a very slight infestation by *Diatraea venosata* in the Galle District. A particular field of three acres showed a stalk infestation of 0·3 per cent. In the other parts of the same region the stalk and joint infestations detected were as low as 0·25 and 0·015 per cent. respectively. The other regions were found to be absolutely free from *Diatraea*. Searches made on other Gramineae likely to be harbouring the insect gave negative results.

4. Under such conditions only a very small number of *Diatraea* larvae could be secured, in fact not more than a dozen. Parasites were not and could not be expected from this insignificant number, but some of the larvae were affected by a fungus disease.

5. Stem-borers of other kinds were also practically non-existent on sugar-cane. The general absence of cane pests is chiefly attributed to cultural methods in use (non-intensive cultivation and rotation of crops). It is possible that fungus diseases constitute also a limiting factor, chiefly in the damp and hot climate of Galle.

6. In view of this scarcity of *Diatraea*, attention was diverted to *Chilo zonellus*, Swinh., a common stem-borer found chiefly on maize and sorghum. The genera *Diatraea* and *Chilo* are fairly closely related, and the species concerned are approximately of the same size, so that it was reasonable to suppose that if *Chilo* parasites could be obtained they would possibly be useful against *Diatraea* in Mauritius.

7. A total of about 3,700 *Chilo zonellus* larvae and pupae was collected from January to March, chiefly from maize stalks. This material yielded four kinds of parasites ; the Ichneumonid *Xanthopimpla stemmator*, Thunb., a pupal parasite, and the Braconids *Bracon albolineatus*, Cam., *Apanteles flavipes*, Cam., and *Macrocentrus* sp., all larval parasites. The description and bionomics of these species are given. Of these parasites the two last named were eliminated, *Apanteles flavipes* already existing in Mauritius on *Diatraea*, and *Macrocentrus* sp., of which only three males were obtained.

8. *Xanthopimpla stemmator* and *Bracon albolineatus* were bred in the laboratory on *Chilo zonellus* with a view to increasing their number for shipment to Mauritius. The breeding technique is described. 80 *Xanthopimpla* and 1,408 *Bracon* were thus reared in Ceylon from an original stock of 7 and 23 females respectively.

9. Two shipments of these species were made, consisting of 58 *Xanthopimpla*, chiefly adults, and 759 *Bracon*, both adults and cocoons ; 48 of the former and 200 of the latter reached Mauritius alive. The length of the voyages was nine and eleven days. The method of shipment is described.

10. From the 48 *Xanthopimpla stemmator* received alive in Mauritius 16 ♂♂ and 13 ♀♀ were immediately released in a *Diatraea* infested field (April 1939). This

parasite was recovered five months after its release, and from May to September 1940, 1,571 individuals were captured in one field and distributed in various places of Mauritius infested by *Diatraea*. It is now well established all over the Island.

11. From the 200 individuals of *Bracon albolineatus* reaching Mauritius alive, 170 were released in the field and 10 males and 20 females reserved for laboratory breeding. This breeding was done on *Diatraea* and *Sesamia* larvae which were readily accepted and successfully parasitised.

The rearing work was carried out for a year, when the stock finally died out in April 1940 ; 7,927 cocoons were thus obtained in the laboratory, 4,865 imagines emerged from them, out of which 2,658 were released in the field. A total of 2,828 adults was therefore liberated in Mauritius. But in spite of this large number the species is apparently not established in the island, and the failure is attributed to the nature of the plant harbouring the host-larvae. It is probable that sugar-cane is not suitable for this parasite.

12. The egg parasite *Trichogramma evanescens*, Westw., was also imported from Ceylon. It was obtained from the Tea Research Institute, which received a stock from Europe for trial against the Tea Tortrix. A small colony reached its destination in good condition and was maintained on various Lepidopterous eggs, ready to be increased at any time by mass breeding for trial against *Diatreaea.*

10. Acknowledgments.

It is with much pleasure that I take this opportunity of expressing my gratitude to all the persons, both scientists and others, who have contributed in various ways to make my stay in Ceylon both successful and pleasant. I am particularly indebted to the Director and Deputy Director of Agriculture for granting every facility to work in the laboratories of the Department of Agriculture at Peradeniya. My sincere thanks are extended to the many officials of the Department, too numerous to name individually, both at Peradeniya and in the Provinces, who have helped me on many occasions by loan of apparatus, identification of host-plants, etc. In this connection I am specially grateful to Dr. J. C. Hutson, Government Entomologist, whose unfailing help and sympathy have been invaluable. I was freely allowed to make use of all records, collections and library of the Division of Entomology, and the assistance received from the whole Entomological staff on several occasions was most valuable. Dr. A. W. R. Joachim, Chemist of the Department, was kind enough to arrange accommodation for me in one of the rooms of his laboratory for the whole period of the investigations. Without this privilege the work would have been certainly handicapped. In the Provinces I always received spontaneous help from the Divisional Agricultural Officers and the Agricultural Instructors : Mr. N. K. Jardine, Agricultural Officer, Southern Division, allowed the Agricultural Instructor, Mr. K. S. Arumugam, to accompany me in the complicated circuits in the sugar-cane areas of the Galle District. The same assistance was received from the Agricultural Instructor at Badulla when visiting the sugar plantations of the Uva Province.

At the Tea Research Institute, St. Coombs, I was received with invariable courtesy by Mr. C. B. Redman King, the Entomologist of the Institute, who arranged for the supply of the stock of *Trichogramma* imported into Mauritius.

At the Colombo Museum, Mr. G. M. Henry and his assistant were kind enough to guide me in the examination of the rich collection of Ceylonese insects of that Institution. I had the most liberal access to the scientific library of the Museum.

To the Imperial Institute of Entomology, London, I am indebted for the identification of the parasites collected in Ceylon.

Finally, I wish to reiterate my thanks to the Honourable G. E. Bodkin, Director of Agriculture, Mauritius, and to Dr. W. F. Jepson, Government Entomologist, for having entrusted to me the work described above, and for much helpful advice and encouragement.

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NOTE ON THE NAME OF THE SUGAR-CANE BORER OF MAURITIUS (LEP., PYRAL.).

By W. H. T. Tams.

The history of this insect is so involved that perhaps the simplest method of attempting to find out how to arrive at its correct name will be to start with a chronological list of the references involved.

[1794. *Phalaena saccharalis*, Fabricius, Ent. Syst., **3** (2), p. 238.]

[1828. *Diatraea*, Guilding, Trans. Soc. Arts, **46**, p. 148.]

1856. *Proceras sacchariphagus*, Bojer, Report of the Committee on the " Cane Borer " (4 plates).

1862. *Borer saccharellus*, Guenée, in Maillard, Notes Ile Réunion, part 2, p.G. 70.

1863. *Chilo mauriciellus*, Walker, List Lep. Ins. B. M., **27**, p. 141.

1873. *Proceras sacchariphagus*, Bojer, Sugar Cane **5**, pp. 158, 302, 432, 447, 534, plates.

1890–1891. *Diatraea striatalis*, Snellen, Tijd. v. Ent. **34**, p. 349, pl. 19, figs. 1–4.

1941. *Diatraea mauriciella* [*sic*] Walk., Vinson, Revue Agricole de l'Ile Maurice **20**, no. 3, pp. 148–153.

Although the venation of the Old World moths of this group appears identical with that of the New World species, the structure of both the male and female genitalia indicates that the Old World species belong to a genus different from that which bears the name *Diatraea*, Guilding, of which the type is the New World *Diatraea saccharalis*, Fabr.

The first appearance under any name of an Old World species of Crambid Sugar-cane Borer is shown by the 1856 reference to *Proceras sacchariphagus*, Bojer. The Report in which the description appears bears on its cover the following information :

Report of the Committee on the " Cane Borer "
(*The right to publish this Report has been specially reserved by the Printer*).

1856

Mauritius :
H. Plaideau, Government Printer, Bourbon Street, Port Louis.

1856

Systematists are continually hindered in their work by quibbles, not the least annoying of which are those relating to the criteria upon which publication is to be regarded as established. Whatever views others may hold, in this case, I am personally satisfied that the above-mentioned report was actually published in the fullest sense, and I should regard as an obstructive quibble any suggestion that the omission from the cover of a sale price affects the case.

I have no hesitation in accepting *Proceras sacchariphagus*, Bojer 1856, as the earliest valid name for this species.

In his " Rectification d'une erreur courante relative à l'espèce de *Diatraea* (Borer ponctué) s'attaquant à la canne à sucre à Maurice " (Revue Agricole de l'Ile Maurice, **20**, no. 3, p. 148) Jean Vinson states :

" En 1862 le lépidoptériste français Achille Guenée publiait une étude sur les Lépidoptères de la Réunion. Il y décrivit l'insecte en question, qui avait aussi trouvé accès, à cette île où sa présence avait été décelée en 1857. Mais, persuadé qu'il se trouvait en présence de l'espèce des Antilles que Fabricius avait nommée *Pyralis saccharalis* en 1794, il ne lui donna pas un nouveau nom spécifique et se contenta de modifier la terminaison de celui de Fabricius en *saccharellus* ' pour la rendre semblable à celle de toute la légion dans laquelle elle rentre.' Le nom générique *Borer,* proposé en même temps par Guenée pour cette espèce ne peut être considéré comme valable puisque longtemps avant, en 1828, Guilding avait crée le genre Diatraea pour l'espèce de Fabricius."

Vinson's reasoning is based on certain misapprehensions.

1. The species which Guenée had before him was, in fact, the Old World Sugar-cane Borer which is the subject of these notes, *viz.* :—

    NOT [*Phalaena saccharalis*, Fabricius 1794, Ent. Syst., **3** (2), p. 238]

    BUT *Phalaena saccharalis*, Fabr., Guenée 1862, non Fabricius—OR *Borer saccharellus*, Guenée 1862.

2. Similarly the genus *Borer*, Guenée 1862, was founded on this same species and not on the New World Fabrician species, and therefore cannot be synonymous with *Diatraea*, Guilding 1828.

Should it be argued that the 1856 publication of *Proceras*, Bojer, is not a publication legal for the purposes of systematic zoology—an argument which I decline to accept—then the next valid generic name would be *Borer,* Guen., as this precedes the 1873 publication of *Proceras* in volume 5 of " Sugar Cane."

The determination of the correct trivial name presents a different problem, affected by similar considerations.

The name *Borer saccharellus* given by Guenée in 1862 to this species, which he erroneously believed to be the same as the New World species, was an entirely new name in fact, if not—in respect of the trivial name only—in intention. Failing then, acceptance of the 1856 Bojer names, the next available and valid names would be *Borer saccharellus,* Guénee 1862.

I am perfectly satisfied with Vinson's arguments in favour of regarding *Diatraea striatalis*, Snellen, as identical with *Proceras sacchariphagus*, Bojer, and entirely different from *Proceras venosatus,* Walker 1863, List Lep. Ins. B. M., **27,** p. 144 (*Chilo*).

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st October and 31st December, 1941 :—

AGRICULTURAL RESEARCH INSTITUTE, WAD MEDANI :—27 Diptera, 141 Coleoptera, 3 Lepidoptera, 120 Isoptera, and 5 Rhynchota ; from the Sudan.

Mr. G. S. COTTERELL, Government Entomologist :—2 Diptera, 10 Coleoptera, 25 Parasitic Hymenoptera, 100 Formicidae, 7 Lepidoptera, 50 Isoptera, 4 species of Coccidae, 1 species of Aleurodidae, 70 Psyllidae, 17 other Rhynchota, and 2 Chelifera ; from the Gold Coast.

Mr. R. A. CROWSON :—6 Diptera ; from England.

Mr. R. G. FENNAH :—237 Coleoptera ; from the British West Indies.

Mr. J. L. FROGGATT, Government Entomologist :—234 Diptera, 115 Coleoptera, 25 Parasitic Hymenoptera, 56 other Hymenoptera, 66 Lepidoptera, 6 Thysanoptera, 4 species of Aphidae, 56 other Rhynchota, 2 Orthoptera, and 4 tubes of Orthopterous parasites ; from New Guinea.

Mr. H. HARGREAVES, Government Entomologist :—205 Diptera, 78 Parasitic Hymenoptera and 38 cocoons, 18 other Hymenoptera, and 25 Lepidoptera ; from Uganda.

Mr. G. H. E. HOPKINS, Medical Entomologist :—16 *Glossina* and 4 slide preparations ; from Uganda.

Mr. J. R. ERICHSEN JONES :—6 Elaterid larvae ; from Wales.

Dr. R. H. LE PELLEY, Entomologist :—23 Diptera, 45 Parasitic Hymenoptera, 17 Tenthredinidae, and 4 Lepidoptera ; from Kenya Colony.

Mr. R. A. LEVER, Government Entomologist :—7 Diptera, 148 Coleoptera and 5 early stages, 101 Parasitic Hymenoptera, 104 other Hymenoptera, 22 Lepidoptera, 1 species of Coccidae, 11 other Rhynchota, 4 Orthoptera, 2 Trichoptera, 30 Mites, 3 Crustacea, 5 Lizards, and 2 Mineral specimens ; from the Fiji Islands.

Mr. J. F. PERKINS :—1,500 Coleopterous larvae and 2 Formicidae ; from England.

THE FOOD AND FEEDING HABITS OF *ANTESTIA* IN KENYA.

By Richard H. Le Pelley.
Department of Agriculture, Kenya.

(Plates II & III.)

Introduction.

Species of *Antestia* have long been known as important pests of coffee in East Africa and have in consequence been studied by a number of workers. But though there are many scattered observations on the food and feeding habits of the insect, little real advance has been made in our knowledge of this aspect of the subject since the observations of Gowdey in 1918. Since 1932, when a study of *Antestia* was begun in Kenya, there has accumulated considerable knowledge, much of it new, of its feeding habits and preferences. This first paper of a series on the ecology of the insect deals therefore with its food and feeding habits, a subject fundamental both to a wider knowledge of the insect, and to a study of methods for its control. As a result of these investigations we now have knowledge of most of the important feeding habits and their results, but it will be obvious that there still remain various aspects of the subject on which further work is required, and the deficiencies in our knowledge will be indicated in the course of this paper.

Host-plants.

In Kenya three host-plants of *Antestia lineaticollis* are known, *Coffea arabica*, *Psychotria nairobiensis* and *Pavetta elliottii*. The insect feeds and breeds on these species without apparently showing very marked preference for any. *Psychotria* and *Pavetta* are both found to harbour a resident population of *Antestia* even when growing in the near neighbourhood of coffee in the Nairobi and Kiambu districts of Kenya. These two plants have been found also to maintain regularly a population of *Antestia*, many miles from the nearest coffee, in parts of the Kikuyu Native Reserve of the Fort Hall district.

The species *Antestia faceta* has not so far been recorded on any plant except coffee, but on both *Psychotria* and *Pavetta* another species of *Antestia*, closely related to *lineaticollis* but apparently a distinct undescribed species, is also found. Biological observations on this species will be dealt with in a further paper.

On *Psychotria*, the *Antestia* feeds on all green parts of the plant ; the berries are attacked from a small size until full-grown, and the fungus *Nematospora coryli* has been isolated from them, which causes a blackening and destruction of the endosperm similar to that found in coffee berries. *Psychotria* often shows a peculiar bunchy growth similar to that which *Antestia* is shown below to induce on coffee, though experimental proof that the insect is responsible has not been obtained in the case of *Psychotria*. *Psychotria* is a small shrub, belonging to the Rubiaceae, common in most parts of the Kikuyu country at elevations at which coffee is grown, and particularly common in Kiambu and Nairobi in the neighbourhood of certain coffee plantations ; its importance as a reservoir of *Antestia* should be studied. A considerable *Antestia* population exists on the plant throughout the year, though mainly because of the scattered distribution of the plant in the bush, the numbers never approach the large populations sometimes found on coffee. When the population on coffee is very high it appears that there is a movement from coffee to the *Psychotria*, though the evidence for this is based only on visual observation, not on accurate counts. In times of scarcity of *Antestia* on coffee, especially when this scarcity is due to the application of control measures and the coffee is in a condition particularly suitable to support *Antestia*, it may well be that the reverse movement takes place and the population is replenished by movement from the *Psychotria* to the coffee. This has not been observed in any particular case, but from a practical point of view it may be accepted as sufficiently likely to make it advisable to eradicate *Psychotria nairobiensis* (and at the same time *Pavetta elliottii*) in the immediate neighbourhood of coffee plantations. I have previously pointed out that in a situation like the Sotik district where the coffee plantations are not usually adjacent to each other but scattered over a large area of country with wide tracts of grass and bush between, the situation in respect of native hosts of *Antestia* may be of great importance. Though opportunity for an investigation of this question has not occurred, there is much evidence from planters' records that severe *Antestia* attacks have quickly followed widespread bush fires near their plantations. If this is in fact the case, it would appear that it could only be due to the movement of adult *Antestia* in front of the fires from the bush hosts to the coffee.

Previous information on host-plants other than coffee is scanty. Anderson (1919) records having found it on the grains *wimbi* and *matama* (millet and sorghum) nearly one hundred miles from any coffee, but gives no further details. Gowdey (1918) and Wilkinson (1924) record having found the bug on several other plants besides coffee, but there was no evidence that any of these were host-plants. Hancock (1926) found *Antestia lineaticollis* var. on species of *Canthium* and *Tricalysia* on islands of the Buvuma group in Lake Victoria " where there is no record of *Coffea arabica* ever having been grown." He recorded it also on a number of other plants, including *Pavetta* sp., in the neighbourhood of coffee estates but considered there was little evidence that the presence of *Antestia* on them was more than temporary. Hargreaves (1936) states that the insect can live and breed on three species of *Canthium*, but " the bug shows no preference for *Canthium* in the vicinity of *Coffea arabica*."

Laboratory Experiments on Food and Feeding Habits.

1. *The Parts of the Coffee Plant selected as Food.*

A number of experiments were set up to determine whether *Antestia* showed any marked preference for different parts of the coffee plant when a choice was given. The first experiments, shown in Table I, were of a preliminary nature and were, in each case, single trials not replicated, carried out in large glass dishes with glass

TABLE I.

Experiment No.	Choice of food offered	*Dish 1.* With 20 adult *Antestia* % loss of weight in 6 days	*Dish 2.* Control without *Antestia* % loss of weight in 6 days	Food preference
1	Ripe red berries	8	3	Red berries and shoots
	Shoots with leaves removed	23	14	
	Large green berries	5	5	
	Leaves	14	9	
	Small green berries	6	8	
2	Ripe red berries	12·3	4·1	Red berries
	Small green berries	7·6	7·5	
3	Ripe red berries	11·4	6·1	Red berries
	Shoots with leaves removed	13·9	15·1	
4	Ripe red berries	10·2	5·6	Red berries
	Leaves	11·8	11·1	

covers. Similar material was placed in each of two dishes, and *Antestia** were introduced into one of the dishes. The large green berries were picked about seven months after flowering, and in most but not all of them the endosperm was hard. The small green berries were between one to three months from flowering, none of them had reached half size, and the endosperm was quite soft. In Experiment 1 five choices of food were given ; in experiments 2, 3, 4 two choices only.

In these preliminary experiments the humidity was not controlled, and it was found that very different results occurred in the control dishes according to the fit of the glass cover ; also that certain classes of food might actually lose more weight in the control dish than in the dish with *Antestia* because the humidity was higher in the dish containing the insects. It was then decided to set up a series of experiments in desiccators with the humidity adjusted over sulphuric acid solutions, and for this purpose use was made of the tables given by Buxton & Mellanby (1934). It was found that the percentage loss in the controls was standardized within reasonably small limits by this means, and the chief difficulties encountered were that the deaths of *Antestia* in the conditions were many, and the feeding limited. In these experiments each desiccator carried its own control berries in wire-gauze covered pill-boxes.

TABLE II.

Desiccator		Choice of food offered	With 20 adult *Antestia* % loss of weight in 6 days	Control without *Antestia* % loss of weight in 6 days	Food preference
No.	Relative humidity %				
1	20	Ripe red berries Large green berries	32·5 33·6	29·5 29·2	No preference ; fed on both
2	20	Ripe red berries Large green berries	33·6 34·6	28·3 27·1	Ditto
3	80	Ripe red berries Large green berries	12·6 11·2	10·6 9·3	Ditto

A series of three experiments, two at 80 per cent. and one at 20 per cent. relative humidity, replicating the comparison six times in each case were then set up, offering large green and small green berries. The results are given in Table III.

TABLE III.

Desiccator		Choice of food offered	With 20 adult *Antestia* % loss of weight in 6 days with standard error	Control without *Antestia* % loss of weight in 6 days with standard error	Difference and S.E. of difference	Food preference
No.	Relative humidity %					
1 to 6	80	Large green berries Small green berries	11·8 ±0·6 30·8 ±2·9	7·8 ±0·5 20·8 ±1·9	4·0 ±0·8 10·0 ±3·5	Small berries ?
7 to 12	80	Large green berries Small green berries	17·6 ±1·0 30·3 ±2·7	8·5 ±0·6 21·9 ±1·3	9·1 ±1·2 8·4 ±3·0	No preference
13 to 18	20	Large green berries Small green berries	35·1 ±2·5 60·1 ±0·9	20·9 ±2·2 55·5 ±0·8	14·2 ±3·3 4·6 ±1·2	Large berries

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* In all cases except where another species is definitely mentioned the species referred to is *Antestia lineaticollis.*

In all these cases feeding was seen to take place on both classes of berry. In the series at 20 per cent. the feeding was mainly on the large green berries, the reason in this case being clearly that the small green berries dried up at the low humidity so as to become unpalatable soon after the start ; even so, the difference in loss of weight between small green berries with and without *Antestia* may be considered significant, showing some feeding to have taken place from them.

The feeding experiments show that *Antestia* will feed on any part of the coffee plant including red berries, large green berries, small green berries, green shoots and leaves. (And it will be shown later that flower buds are also fed on.) Given a choice of foods, red berries and large green berries are preferred ; small green berries and shoots are usually less favoured ; and leaves are seldom chosen in the presence of other food.

2. *Length of Life, and Reproduction on different Foods.*

A series of experiments to determine the influence of the different parts of the plant as food were set up in cages. In the first of these experiments, each cage with different food contained four females and three males. The length of life and egg production was observed. Previous to the confinement on special food the insects had fed for varying periods on mixed food consisting of green and red berries and leafy shoots ; this in the conditions was unavoidable, and the times are given in the first column.

TABLE IV.

Average life in days on mixed food		Cage	Food	Average life in days on restricted food		Average egg production per female after beginning restricted feeding
Females	Males			Females	Males	
10	10	1	Red berries	24	24	0
10	10	2	Large green berries	98	111	98
9	9	3	Small green berries	22	20	0
7	6	4	Shoots with leaves	29	37	0
5	2	5	Shoots with leaves removed	67	35	0
3	1	6	Leaves	23	20	0
18	18	7	No food, water only	6	4	0

As a result of this experiment it would appear that large green berries are essential for egg production. That this might not be strictly the case is indicated by a further series of similar feeding trials (Table V) in which each of the above classes of food was offered to five females and five males. These had all fed on mixed food, including large green berries, previous to the special feeding, so that the experiment does not prove certainly that the insects can reproduce without at any time having large green berry food. This point will be settled later by experiment.

The fact that large green berries are essential to normal length of life and normal egg production is considered proved as a result of the feeding trials, and this is the point of most practical importance. In the case of the red berries, which it has been shown are a favourite food, it will be shown later that the bean is seldom pierced ; the feeding must therefore be almost entirely on the sugary pulp, and it is clear from results in Tables IV and V that this is not a complete food.

TABLE V.

Average life in days on mixed food		Cage	Food	Average life in days on restricted food		Average egg production per female after beginning restricted feeding
Female	Male			Female	Male	
30	30	1	Red berries	34	37	0
27	27	2	Large green berries	86	86	19
20	20	3	Small green berries	36	32	1
15	15	4	Shoots with leaves	51	65	9
10	10	5	Shoots with leaves removed	52	38	6
3	3	6	Leaves	34	15	6

3. *Growth from Egg to Adult on different Parts of the Plant.*

No difficulty has been found in the Kiambu and Nairobi districts in rearing *Antestia* from egg to adult on green coffee shoots only, though the deaths on this food are undoubtedly higher than when berry food is provided. In one series of rearings from the egg it was found that on large green berries, small green berries, shoots with leaves, and shoots with leaves removed, the insects arrived at the adult stage, but on red berries some of the insects reached the third instar but none reached the fourth, and on leaves only none reached the third instar.

Feeding on the Berries.

1. *Inoculation of* Nematospora *spp.*

It has always been recognised that the berries are the chief food of *Antestia*, and for many years it has been known that *Antestia* caused a blackening of the coffee bean ; Wallace (1930, 1931) showed that the fungus *Nematospora coryli* causes a rotting of the endosperm and is introduced into the bean by *Antestia*. Later (1932, 1932 *a*) he found *Nematospora gossypii* to be equally destructive. Both *N. coryli* and *N. gossypii* have been recorded from coffee beans in Kenya (McDonald 1932, 1933), but *N. coryli* is the more common. These fungi belong to the group known as stigmatomycosis fungi, which develop only in the fruits of plants, the only known method of transmission being by insect feeding. The damage when advanced causes complete loss of the bean, which floats off in the washing channel, and in less advanced cases causes a blackening of the bean, which has then to be removed by hand-picking during preparation. Beans which are only very slightly affected at the time of picking may find their way through to the market, but coffee containing even a few of these beans is usually of a tainted liquor. This may not be because the fungus itself is foul, but because chipped or damaged beans pick up taints which are always liable to be present during fermentation.

Detailed mycological and bacterial observations would be necessary to solve all the problems raised by the feeding of *Antestia* on coffee berries. While it is certain that *Nematospora* is usually present as a result of *Antestia* attack, it seems probable that other organisms may also be implicated. Small (1923) showed that *Antestia* was able to introduce a species of *Phoma* into the tender tissues of young beans. He stated that the fructifications of the *Phoma* can afterwards be found on the cured beans and that their presence and development add considerably to the direct harm caused by the sucking of the bug. Still other fungi and bacteria may be responsible for a portion of the rotting which occurs. Notley (1941) records that *Nematospora* was isolated from 83 per cent. of a sample of beans which were seen to be stained. My own experience is that *Nematospora* can usually be isolated from full-grown green berries in which infected *Antestia* have been allowed to feed some time previously, but the course of development of the fungus in the bean has not been followed in detail, and in some cases, especially of very young berries with the endosperm soft and semi-liquid and where blackening had certainly taken place, *Nematospora* could not be found. In this connection the observations of Wallace (1930) on coffee cherry fall are of interest. He states :—

> " . . . . black beans are encountered. In this case, however, no parasite has " been observed, and the effect appears to occur even in the absence of antestia. " The actual fall of cherries appears to be one symptom of a physiological weakness " in the trees ; the coffee tree is very prodigal in its production of flowers and fruit, " but under some conditions there are indications that it has borne fruit in excess " of what it can successfully mature. The excess fruits are denied an adequate " supply of sap by the formation of a layer of corky cells ; the latter are mealy " to the naked eye. This barrier forms at the base of the cherry stalk or at the " base of the fruit itself."

In the present paper it is shown later that *Antestia* is responsible for a heavy fall of young cherries, and in all the cherries which fell as a result of *Antestia* attack the beans were black, soft and moist, as described by Wallace for this non-parasitic cherry fall. Moreover the beans were seen to fall as a result of the formation of mealy cells in the pedicel. As will be shown later, this method of shedding occurs also in the case of berries attacked by fruit-fly and berry-borer moth. Whether or not it is a normal method by which the tree can shed uninjured, as well as injured berries, is not certain, but in all the experiments herein described it did not occur in the case of any protected berries. What shedding took place in protected berries, due presumably to causes connected solely with the physiological condition of the tree, was of very small berries only, and these dried up completely together with the pedicel, with no production of mealy cells. It seems likely that a large part of the cherry fall described by Wallace and ascribed to physiological causes is in fact due to *Antestia*. Another condition known as black bean has been described by Venkatarayan (1938), in which the black bean is associated with the absence of the embryo ; he states that the affected fruits do not drop off but remain on the plant till the other fruits mature. It is clear that further investigation of the problems of the rotting and dropping of coffee berries is required. From the point of view of the East African coffee planter, however, the problems are not of great practical importance, because the only means by which a definite rotting can develop in berries where the skin is not obviously damaged (except that occurring in coffee berry disease, caused by *Colletotrichum coffeanum*) is by the introduction of a pathogenic organism through insect feeding, and the only insects implicated or sufficiently numerous to be of importance as vectors in Kenya are species of *Antestia*.

2. *Berries protected from Insect Feeding.*

A cloth sleeve was placed over a shoot before flowering and kept on for six or seven months until the berries produced were full-grown and green with endosperm hard. Fifty-two berries containing 107 beans were examined, and they showed no rot of any kind.

3. *Berries of different Ages exposed to Antestia Feeding.*

A number of berries of different ages were exposed after picking to *Antestia* feeding for periods of four to six days and the beans examined on the last day. An equal number of beans protected from feeding after picking were examined in each case, being from berries chosen at random from the same stock as those supplied to the *Antestia*. In the last column of Table VI is included any bean which showed a definite brown or black spot in the endosperm. At the time of these tests no protected berries were available, so the figure of beans rotted in the controls gives the natural infection in the field at the Scott Agricultural Laboratories, Nairobi.

TABLE VI.

Class of berry	Number of beans	Treatment	Beans rotted
Small green	432	Fed to *Antestia* after picking	263
,, ,, ...	432	No *Antestia* after picking	7
Large green	202	Fed to *Antestia* after picking	140
,, ,, ...	202	No *Antestia* after picking	5
Ripe red	74	Fed to *Antestia* after picking	3
,, ,, ...	74	No *Antestia* after picking	2

The table shows that the berries are fed on and may be attacked by rots from the young stage to the full-grown green berry with hard endocarp (parchment), and it shows that in the case of the red berry the feeding is chiefly on the pulp, the endocarp probably not being pierced at this stage. In the field the small green berries on the tree are found to suffer from rots introduced by *Antestia* at least to the same extent as the full-grown green berries. An example may be given of small green berries averaging about the size of a pea resulting from a November flowering, picked and examined in January ; 250 beans were represented in the sample, 159 showed a brown or black spot, while 91 appeared healthy. In the block of coffee from which these berries were picked spraying tests for *Antestia* in December and January had shown an average of eight and nine *Antestia faceta* to a tree.

4. *Amount of Damage to full-grown Green Berries in the Field.*

The damage to the full-grown green berries varies considerably in different cases in the field, and the actual loss in any particular case is not very closely correlated with the number of *Antestia* present. Figures bearing on this question were obtained in plantation sprayings. One test spraying was made on five trees, and on the same day 100 full-grown green berries were picked in the area of spraying and the beans examined for *Nematospora* damage or other rots. It would hardly be expected that figures so obtained would give a close correlation between the number of *Antestia* and the amount of damage ; and, in fact, the figures (which are plotted in text-figure 1) are too widely scattered to warrant their use to obtain a theoretical formula. But a formula has previously been used to represent the case of a population of animals searching a very large area of random (Thompson 1924) ; and the curve drawn in the diagram is of the same type, with the formula $P=100\ (1-e-^{0\cdot 02A})$, where P is the percentage of berries damaged, e the base of the Napierian logarithms, and A the average number of *Antestia* to a tree. The assumption that the searching of the insects for food is at random is of course unjustified, but it may be true in considering populations of *Antestia* and very large numbers of berries, and it will be seen that the points, while scattered, are fairly well represented by this curve. One further point in the same series is omitted from the diagram ; it is of 343 *Antestia* to a tree with 97 per cent. damage to beans.

The curve rises steeply at first, because at first very few berries are likely to be attacked twice ; later less steeply, because as the number attacked increases there is a greater likelihood that a berry selected will have been previously attacked.

The practical conclusion from the above results is that *Antestia* should be controlled when the population is low or serious damage to the crop will occur. The other types of damage proved in this paper substantiate the soundness of this advice.

Notley (1940) gave figures of the percentage of beans damaged by *Antestia* in conditions of low *Antestia* populations which did not exceed an average of three to a tree. He found considerable damage to be caused, running up to 24 per cent. and sought to demonstrate the correlation between average number of bugs and percentage of beans damaged with a straight line curve. It seems reasonable to assume that as the numbers of *Antestia* were very low this straight line represented the approximately straight portion of a curve of the type used here, which would have been obtained if higher *Antestia* populations had been available.

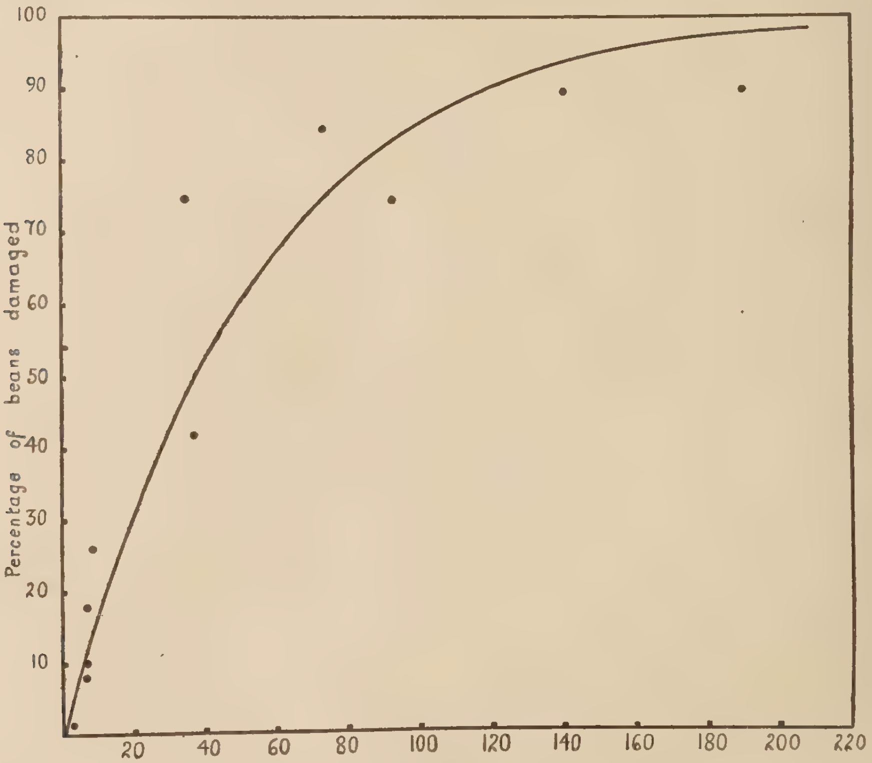

Fig. 1. Average number of *Antestia* to a tree.

5. *Berry Fall as a result of Antestia Feeding.*

As there has been considerable speculation on this question, which has not hitherto been proved,* an experimental investigation was made.

Sleeves were placed on two primaries of each of ten coffee trees which had recently flowered. On these sleeved primaries the berries were thinned with scissors to prevent shedding through overcrowding during growth, four berries only being left on each side of each node in the *Antestia* and control sleeves. In each of ten sleeves ten adult *Antestia* were introduced, there being a corresponding control sleeve without *Antestia* on each tree. The results are given in Table VII. The last column headed " + or — " requires explanation. The plus sign indicates that more berries were found at the end than should have been there according to the original count ; the minus sign indicates berries not found at the end which should have been present. It should also be mentioned that the deaths of *Antestia* were rather high in the sleeves, all but twelve were dead by 21st April, when another 100 were introduced. Only ten of these were alive on 12th May and they were then removed.

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* After the preparation of this paper my notice was drawn to an article by J. V. Leroy & F. L. Hendrickx in " Centre Afrique," No. 393, 13th March, 1941, in which dropping of berries is attributed to *Antestia*.

TABLE VII.

Treatment	Sleeve	Berries present at start March 28th	Berries dropped by					Berries left May 19th	+ or —
			April 21st	April 28th	May 5th	May 12th	May 19th		
10 Adult *Antestia* introduced 28th March in each sleeve. 10 Adult *Antestia* introduced 21st April in each sleeve.	1	75	9	17	32	34	36	34	−5
	2	36	1	3	4	9	13	22	−1
	3	63	6	7	9	12	13	48	−2
	4	53	0	9	13	16	19	35	+1
	5	54	5	36	42	44	44	8	−2
	6	85	6	17	27	37	42	43	0
	7	68	10	26	40	48	50	17	−1
	8	47	3	16	26	32	32	14	−1
	9	54	7	16	29	38	39	13	−2
	10	58	16	18	29	50	54	1	−3
TOTALS ...		593	63	165	251	320	342	235	−16
Each sleeve protected from *Antestia* throughout.	1	51	0	0	0	0	0	51	0
	2	63	0	0	0	2	2	61	0
	3	52	0	0	0	0	0	52	0
	4	54	0	0	0	0	0	51	−3
	5	60	0	0	0	0	0	60	0
	6	91	0	0	0	0	0	91	0
	7	51	0	0	0	0	0	49	−2
	8	53	0	0	0	0	0	53	0
	9	59	0	0	0	0	0	59	0
TOTALS ...		534	0	0	0	2	2	527	−5

It will be noticed that control sleeve 10 is not represented in the table. On 28th April some berry fall was noticed in this sleeve which was opened for examination, and one fifth instar *Antestia* nymph was found in the sleeve, which it seems likely was present, though unobserved, probably in the third instar, when the sleeve was placed on the shoot. Sixteen berries fell from this shoot up to 19th May, but the development of the remaining fifty berries proceeded normally.

In this feeding trial there was, in a period of less than two months, a fall of over 50 per cent. of the berries in the ten sleeves with *Antestia*, every sleeve showing some fall, while the control sleeves showed no comparable fall and every dropped berry showed blackening of the endosperm due to *Antestia* feeding. Further, the development of the berries proceeded absolutely normally in the control sleeves, the berries being large and well filled, in striking contrast in every case to the small underdeveloped berries in the *Antestia* sleeves. No other primary, whether sleeved or unsleeved, on any of the ten trees, carried similar small berries at the conclusion of the experiment.

The fall of berries in the sleeve experiment appears not to be due to the insect feeding on the stalks. It was brought about by an abscission characterized by a mealy appearance which appears to result from a separation of the cells due to dissolution of the middle lamella. The physiological process by which this abscission is brought about is not known, but it is doubtless a response to a depletion of food material in the berry brought about by the feeding of the insect and the action of any organisms which may be introduced at the same time. Heavy berry fall of young green berries has been observed in Kenya when an attack of fruit-fly (*Ceratitis capitata*), which normally attacks only ripe berries, occurred on them. In this case the fall could only have been through a process of shedding by the plant, as the fly larvae did not feed on the pedicel. Large and small green berries also fall as a result of attack by the berry moth (*Thliptoceras octoguttalis*, Feld.) ; in these cases too where the abscission occurs the mealy appearance is present though the insect does not feed on the pedicel.

When attacked by *Antestia* the berries fall at the very smallest size and at all sizes up to the half-grown berries. The maximum age up to which berries may be shed as a result of the insects' feeding was not definitely determined, but it is known that berries in which the endosperm is hard are not normally shed as a result of *Antestia* feeding.

In the field it is commonly observed that berry fall occurs when *Antestia* is present in numbers ; the following count of the berries under three trees is fairly typical.

TABLE VIII.

Tree	Number of berries on tree (estimated)	Berries dropped on ground	No. of *Antestia* on tree
1	1,200*	186	Not known. Average for block 52
2	1,800*	256	Not known. Average for block 52
3	300*	33	15

* Approximately 4, 6 and 1 cwt. " clean coffee " per acre.

Anderson (1919) believed that berry fall is caused " in some instances especially when the stalks have been attacked." Ritchie (1929) has recorded berry fall thought to be caused by *Antestia*. Gowdey (1918) made the most definite statement on this question—he said " by sucking the berries—the newly set as well as the well-developed berries—it causes them to drop."

Feeding on the Flower-buds.

1. *Description of the Damage to Flower-buds.*

An important part of the damage done by *Antestia* is to the flower-buds, and the insect must rank as one of the important causes of the non-setting of flowers. *Antestia* frequently feeds on flower-buds and has been observed to do so, but not of course exclusively, when berries are also available. The flower-bud from a very early stage before it is recognizable as an individual spike,† and all through the spike stage until it flowers, is attacked and turns brown or black, and the flower fails to set. The petals, stamens with anthers, and the style, are all involved, the whole spike consequently blackening and shrivelling as a result of the feeding. There seems little doubt that a considerable amount of the damage caused to flower-buds when both *Lygus coffeae*, China, and *Antestia* are present together has been attributed to *Lygus*, though actually caused by *Antestia*. In practice this has not mattered because the control by pyrethrum extract spraying or pyrethrum dusting is the same for both bugs, but the damage may usually be distinguished as follows : *Lygus* feeds on the anthers, which go black, the petals subsequently going black also, but the style is not normally fed on by this insect and on dissecting the flower, the style is seen to be white and uninjured ; sometimes the style continues to grow and lifts up the black cap of stamens and petals exposing a portion of the style below. On the other hand, after the feeding of *Antestia* the petals, stamens and style are all destroyed. The writer (1932) in discussing causes producing abortion of coffee flowers did not mention *Antestia* as one of them because at that time opportunity of determining this by experiment had not occurred.

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† There are two local expressions for stages in the development of the coffee flower which are in such general use that it is considered advantageous to retain them here.

(1) Flower " spike " is used for the individual flower bud from the time when it is first recognizable as such, until it opens in flower. It is in fact equivalent to the flower-bud in the strict sense.

(2) " Flower-bud " is used to include not only the flower spike, as defined above, but also an earlier stage when the individual flower-buds are not separate, but are present in what would be correctly termed an inflorescence bud.

2. *Experiments in Cages and Sleeves.*

A number of feeding experiments in cages and sleeves, results of which are given in Tables IX, X and XI, prove that *Antestia* causes abortion or non-setting of coffee flowers, and also a malformation of growth characterized by duplication or multiplication of shoots from a growing point which normally should produce a single unbranched shoot. This form of damage is included in the tables, where it is called " multiple branching," and it receives further mention in a later paragraph.

(*a*) *Type of cage used.*—The cage used was a large cage of wood covered with muslin and with wire netting for supporting the muslin ; it was divided into three compartments, each being large enough to contain a four-year-old coffee tree. Two of these compartments were undivided and each contained a glass window for observations and through which it was possible to enter the cage. The third compartment was divided into two approximately equal portions by a wood and cloth partition in which were eight holes with short sleeves, through which eight primary branches of the tree were inserted, the sleeves being then tied with string round a pad of cotton wool at the base of the primary. The caged trees were then used as follows : In No. 1 *Antestia* were introduced ; No. 2 was held free from *Antestia* as a control ; while with No. 3 the main part of the tree was free from *Antestia* as a further control, and *Antestia* was introduced into the section of the cage containing the eight shoots. There was a window in each section of this compartment. Plate II, fig. 1, is a general view of the cage, and fig. 2, shows the third compartment with part of the cloth end removed for purposes of the photograph. This set-up is described at some length as it should prove of more general value as a satisfactory means of experimentation in similar problems. It enables a definite result to be obtained without using large numbers of trees, because factors such as genetical constitution and soil differences, which vary from tree to tree, are eliminated. The experimental tree is its own control. A single similar cage was used by the writer (1932) in studies of the feeding of *Lygus coffeae*, China.

(*b*) *Results.*—From the results of this experiment, which are set out in Table IX, it will be seen that *Antestia* almost completely prevented flowering in the conditions and also severely damaged the vegetative growth. The same or a similar result would have been obtained with fewer *Antestia* ; the number used was large because it was noticed that many of those introduced stayed away from the tree on the cloth, but the proportion visiting or residing on the tree must have been underestimated. Likewise in the sleeve experiments which follow, more insects were introduced than would have been needed to prove the various types of damage.

TABLE IX.

1	2	3	4	5	6	7	8	9		
Cage	Treatment	December 6th	January 8th	January 16th	January 23rd	February 8th	March 21st	Summary of position on March 21st		
								Berries present	Growth made	Multiple branching
1	192 *Antestia* introduced between October 5th and December 24th	A few flowers only, much black spike, new growth only 1 in. to 1½ in., an indication only of multiple branching	Sprayed pyrethrum kerosene extract; all *Antestia* killed	Nearly all spike black a few berries only. Of 64 shoots 45 show definite multiple branching, not more than 2 in. new growth anywhere, in places none at all	5 primaries with berries which total 35, shoot with multiple branching photographed	No flowering	13 berries only remain from November flowering, no flowering since, multiple branching severe, no normal growth, green wood up to maximum of 6 in. only	13	Up to 6 in.	Yes
2	None	Flowers and spike healthy but main flowering obviously later on this tree, all spike healthy, new growth 2 to 4 in., no multiple branching	Sprayed pyrethrum kerosene extract	All spike healthy, new growth up to 10 in., no multiple branching, tree every appearance of health, main flowering still to come	16 primaries with berries which total 81	Large flowering just over	Small flowering November, main flowering January, 62 well-developed berries now present from November flowering, 1,706 small berries from January flowering, growth normal, no multiple branching, green wood up to 20 in.	1,768	Up to 20 in.	No
3 Sleeved section	174 *Antestia* introduced between October 5th and December 6th	No flowers, buds black, less than 1 in. of new growth, terminal leaves injured, indication of multiple branching	Sprayed pyrethrum kerosene extract; all *Antestia* killed	No flowers, all spike black, new growth averages less than 1 in., tip leaves damaged, definite multiple branching despite little growth of shoots	No berries	No flowering	No flowers or berries either in November or January, 13 shoots out of 17 show multiple branching, one shoot dead	None	Less than 2 in.	Yes
Protected section	None	Full flowering (many hundreds), a few black spikes on one branch where two-fifth instar nymphs (escapes) were found and removed, rest of spike healthy, new growth 3 to 4 in., no multiple branching	Sprayed pyrethrum kerosene extract	Good crop on tree, new growth up to 10 in., tree normal in all respects, no multiple branching	36 primaries with berries which total 1,447	A small normal flowering	Tree very similar type to that of Cage 1, main flowering November, smaller flowering January, 1,153 berries now present from November ber flowering, 203 berries from January flowering, no multiple branching, green wood up to 18 in.	1,356	Up to 18 in.	No

The results of sleeve experiments showing further the effect of *Antestia* feeding on the flower-buds and vegetative growth are given in Tables X and XI.

TABLE X.

1	2	3	4	5	6	7
Position of sleeve	Sleeve No.	Treatment	No. of nodes on shoot	December 16th	February 17th	April 23rd
Opposite primaries on one tree	A1	15 *Antestia* introduced Oct. 3rd 22 *Antestia* introduced Oct. 14th	12	*Antestia* all dead, no flowers, all flower-buds black, no new growth, terminal leaves damaged	No flowers, no fruit set	No berries, multiple branching present
	C1	None	6	Perfect flowering and growth	61 berries set	Crop and growth normal
Opposite primaries on one tree	A2	15 *Antestia* introduced Oct. 3rd 22 *Antestia* introduced Oct. 14th	8	*Antestia* not all dead, no flowers, all spike black, no new growth, terminal leaves damaged	Shoot dead	
	C2	None	7	Perfect flowering and growth	92 berries set	Crop and growth normal
Opposite primaries on one tree	A3	15 *Antestia* introduced Oct. 3rd 21 *Antestia* introduced Oct. 14th	7	*Antestia* all dead, no flowers, all spike black, no new growth, terminal leaves damaged	No flowers, no fruit set	No berries, multiple branching present
	C3	None	9	Perfect flowering and growth	110 berries set	Crop and growth normal

In addition, five other sleeves were set up without *Antestia* as additional controls on 4th November. On 17th February there was fruit and normal growth in all five. On 21st March, there were 202, 222, 232, 190 and 149 berries in these sleeves and the growth was normal in all respects. The results of these feeding experiments in sleeves prove that *Antestia*, if present in sufficient numbers, can destroy all flower-buds. The case of A5 is of interest ; here the single female introduced on 12th November was alive on 6th December and observed to be dead by 3rd January, when it had obviously been dead for some time, and there was a good deal of healthy spike left. Another single female was introduced on 3rd January, and on 17th February, when the female and eleven nymphs up to the third instar were present, fifteen flowers had opened and set. The *Antestia* were removed, and on 23rd April all the berries had dropped and the shoot was bare of berries and flower spike.

TABLE XI.

1	2	3	4	5	6	7	8
Position of sleeve	Sleeve No.	Treatment	No. of nodes on shoot	November 29th	December 6th	February 17th	April 23rd
On one tree	A4	30 *Antestia* introduced November 4th	38	No flowers, all flower-buds black	No flowers, all spike black, no growth of shoot, tips black	No fruit set, all spikes black, multiple branching	No berries, marked multiple branching
	C4(a)	None	49	Flowers and healthy flower-buds	Normal flowering and growth	Growth and cropping normal; 175 berries set	Normal shoot
	C4(b)	None	30	do.	do.	Growth and cropping normal; 205 berries set	do.
	C4(c)	None	Not ascertained	do.	do.	Growth and cropping normal, berries too many to count	do.
On one tree	A5	1 female *Antestia* introduced November 12th; this dead on January 3rd; 1 female introduced on January 3rd	22	Some spike spotted, rest appears healthy	4 flowers open, some apparently healthy spike, rest black, slight growth	1 adult and 11 nymphs present, 15 berries set, spike mostly black	No berries, poor growth but no multiple branching
	C5	None	26	Spike more advanced, healthy and nearly flowering	Perfect flowering, too many to count, more growth of shoot than in A5	Growth and cropping normal; 100 berries set	Normal shoot
On one tree	A6	6 females and 4 males introduced November 12th	52	Some large spike; this is being damaged	No flowers, all old spike black, tips damaged, no growth	No fruit set, all spike black, multiple branching present	No berries, definite multiple branching
	C6	None	44	Spike healthy, nearly flowering	Normal flowering, healthy spike and growth	Growth and cropping normal; 136 berries set	Normal shoot
On one tree	A7	Five 5th-instar, four 4th-instar *Antestia* introduced November 12th	Not ascertained	Spike blackening	No flowers, spike black, tips damaged, very slight growth	No flowers, spike black	No berries, poor growth but no multiple branching
	C7	None	do.	Spike healthy, nearly flowering	Some flowers, rest of spike healthy, growth at tip	Flowering and growth normal, many berries remaining, spike healthy	Normal shoot; 243 berries
	Af1	Five adult, five 5th-instar *Antestia faceta* introduced December 13th	do.			No flowers opened, much damage to spike, black tips	No berries, leaves distorted, marked multiple branching
No special control for this sleeve	Af2	Five adult, five 5th-instar *Antestia faceta* introduced December 13th	do.			No flowers, all spike black	No berries, marked multiple branching

Previous authorities have referred to *Antestia* feeding on flower-buds. Anderson (1919) stated that the puncturing of flower-buds causes a reduction in the amount of fruit produced. Kirkpatrick (1937) considered that *Antestia* seldom sucks flower-buds except in the absence of berries, and he added " whether it then causes abortion or shedding I am unable to say for certain." The clearest statement on the question up to the present was the earliest, namely, Gowdey's (1918) ; he stated that " there is no doubt that the variegated bug is responsible for the non-setting of flowers." This statement was apparently a result of keen observation rather than of experimental proof, which proof is given here. It remains to determine by experiment how many flower-buds are destroyed by one, or a given number of *Antestia*, and this should be determined in the presence of various different classes of food.

Feeding on the Leaves.

In the field, developed leaves are seldom fed on, because even in the complete absence of crop the shoots will be preferred to leaves, but the shoot is frequently fed on at the growing point and the very young leaves are often damaged, becoming scarred and sometimes distorted. This has been definitely proved by numerous experiments in cages and sleeves. From this damage, incurred at an early stage, the affected leaves never recover, though later leaves from the same shoot, if not attacked, may of course develop normally. This damage to leaves is not of major importance.

Feeding on the Shoots.

1. *Multiple Branching.*

A common observation after *Antestia* has been present in coffee is that the trees show a " bunchy " type of growth, which in severe cases approaches a " witches-broom " effect ; in less severe cases the growing point is killed or " stopped " and two or more small branches grow from this point where only one should normally be.

This has already been referred to, and evidence that it follows attack by *Antestia* given in Tables IX, X and XI. This evidence may be briefly summarized here :—

Cage 1, with *Antestia* :—Most shoots show definite multiple branching, others show stopping or reduction of growth, growth of whole tree is typically " bunchy." A typical shoot from this cage, showing multiple branching is shown in Plate III, fig. 2, with a healthy shoot for comparison, in fig. 1.

Cage 2, without *Antestia* :—Growth completely normal, no multiple branching, " open growth."

Cage 3, protected section without *Antestia* :—Growth completely normal, no multiple branching, open growth.

Cage 3, section with *Antestia* :—Thirteen shoots out of seventeen show multiple branching, growth of all much reduced.

Out of nine sleeves with *Antestia*, one primary was killed, six showed multiple branching, in two the shoot was not branched but growth was reduced. The control sleeves showed normal growth in every case.

Almost all writers on *Antestia* have mentioned this abnormal type of growth ; these include Gowdey (1918), Anderson (1919), Hargreaves (1930), Wilkinson (1924), Le Pelley (1932 *a*), Kirkpatrick (1937) and Smee (1931), but it appears that only the last named has produced it experimentally. Smee recorded that " by caging specimens of the insects [*Antestia variegata*, Thunb.] on apparently healthy coffee trees proof was obtained that [*Antestia*] was alone responsible." In the absence, however, of further details of these experiments confirmation was necessary.

2. " *Die-back* " *as a result of Antestia Feeding.*

The shoot that died in sleeve A2 (see Table X) and the one that died in the section of Cage 3 with *Antestia* (see Table IX) were unquestionably killed by *Antestia* ; not one protected shoot showed any sign of die-back, but the amount of feeding may well have been more than would ever occur in natural conditions, and the fact that other shoots supported such an amount of feeding without dying, argues that die-back would rarely occur as a result of *Antestia* feeding in the field. Anderson (1919) is the one authority to mention die-back in connection with this insect—" Sometimes when the terminal buds are punctured the shoots die back for some distance."

3. " *Stopping* " *or Reduction of Growth as a Result of Antestia Feeding.*

This has already been mentioned but requires some further description. The result of *Antestia* feeding is a marked reduction in growth, as is seen clearly in Table IX. The feeding results in a shortening of the internodes, which may be very marked, and this appears always to be the first effect ; the duplication or multiplication of branches from the node is a later effect, and together they give rise to the typical " bunchy " or " matted " growth. In practice the production of this bunchy growth is of great concern, the tree may become so thick and matted as to be useless as a crop bearer and to give great difficulty in pruning. After a severe attack by *Antestia* in the Kiambu district the following figures showing pruning differences in attacked and unattacked trees were obtained.

Trees in block free from (or very slightly infested with) *Antestia* :—60 trees pruned by one man in 8-hour day.

Trees in block where there had been an average of 30 *Antestia* to a tree :—14 trees pruned by one man in 8-hour day.

In some cases the damage to the vegetative growth is so severe that planters despair of shaping the tree again, and either " parrot-perch " or stump the tree.

Conclusions.

It has been shown that *Antestia* will feed on any green part of the coffee tree, and that the damage is more extensive and severe than any single writer has recorded. Thus there is damage to leaves, shoots, flower-buds, young and old berries, and the damage to all these portions of the plant, except the leaves, is of economic importance. The figures of damage to the berries show that a very small number of *Antestia* can cause appreciable loss, which, because of the inoculation of a berry-destroying fungus, is out of all proportion to the loss which would result from the sucking, if this only entailed the removal of plant material. During the development of the crop, therefore, it is necessary to keep the numbers of *Antestia* down, and in practice it has usually been advised that an average of four *Antestia* to a tree should be the maximum allowed ; but it is clear that the loss at this figure is not negligible, and no doubt it would often pay to control them to a lower figure. Whether this figure should be one *Antestia* to a tree (see Notley 1940) depends on various factors concerning the economics of the particular coffee concerned. While in coffee on a research station it is advisable not to allow the bugs to increase beyond one a tree, in general practice it is unlikely that planters will spend money on control measures until the numbers are high enough to do damage they can readily appreciate.

The fact that large green berry food is essential to normal life and reproduction is of considerable importance ; from it results the fact that in undisturbed conditions a large increase in *Antestia* can occur only during the growth of the berry and does occur at this time unless inhibited by other factors. This gives a semblance to a definite breeding season, even though the bug is present in all stages, and reproduces at all times of the year. By the time the coffee is ripe, therefore, the *Antestia* population is likely to be at a maximum. And at this time, because of its particular partiality for the pulp of the ripe berry, it probably does less damage than at any other time. By this time much damage will already have been done through infection of the growing beans, yet if the bugs have been allowed to increase, there is nevertheless particular reason for reducing the number of bugs before the crop is removed, because once the berries are off, heavy feeding occurs on the shoots with consequent serious malformation of growth, which in some cases may be so severe as to destroy the cropping capacity of the tree for more than a season.

One other point to consider arises from the necessity of large green berry food for reproduction. If this food is available throughout the year *Antestia* may be able to reach and maintain themselves in large numbers ; if, on the other hand, there is a definite season during which such food is not present, reproduction will undoubtedly be inhibited. Intermittent flowerings therefore are disadvantageous, and this has also been shown to be the case in respect of damage by the flower-feeding bug *Lygus coffeae*, China (Le Pelley 1932). Any cultural practices therefore which tend to induce a single heavy flowering, rather than a number of smaller flowerings following each other, is of advantage. It is certain that something may be done towards this end, though this is outside the scope of the present work.

The results emphasise the necessity for control of *Antestia* at all times, and in practice the " routine testing method " (Le Pelley 1934) has proved of great value. It gives a detailed knowledge of the numbers and distribution of the insects in the coffee and so enables an adequate control of the insect to be achieved at minimum expense, through pyrethrum dusting. These methods are well known in Kenya, but the results of experimental work on the various control measures have not been published in detail and will be the subject of a further paper.

Summary.

(1) Two host-plants of *Antestia lineaticollis* in addition to *Coffea arabica* are *Psychotria nairobiensis* and *Pavetta elliottii*.

(2) Laboratory experiments showed that red berries and large green berries are favoured foods, but feeding will also take place on small green berries, on shoots, and on leaves.

(3) Feeding trials showed that large green berry food is essential for normal length of life and normal egg production.

(4) *Antestia* was reared to adult stage when fed exclusively on large green berries, on small green berries, and on shoots, but not on red berries or leaves.

(5) In large green berries and small green berries the endosperm becomes infected with rots, usually caused by the fungi *Nematospora coryli* or *Nematospora gossypii*, which are introduced by *Antestia*, but in the case of ripe red berries the endocarp is seldom if ever pierced and rotting of the endosperm is not initiated at this stage.

(6) The amount of damage caused to the crop by rotting of the beans is related to the number of *Antestia* present, and a formula which is considered to represent this relationship is given. In practice as high a proportion as 97 per cent. of the beans have been found rotted when *Antestia* is numerous. The figures also show that even when *Antestia* population is low, an economically important amount of damage to the crop may occur.

(7) *Antestia* was proved to cause a dropping of young green berries. This seems not to be due to the insect feeding on the stalk, but to be a response by the plant to an interruption of normal growth of the bean due to insect feeding. A similar shedding has been noticed of berries damaged by other insects when it is known that no feeding on the stalk can have taken place.

(8) Feeding experiments in cages and sleeves showed that *Antestia* must rank as one of the important causes of the non-setting of flowers ; this form of damage has been neglected or minimised in the past.

(9) As a result of *Antestia* feeding on the growing point, leaves become scarred and distorted.

(10) A useful form of cage for experimental work of this kind is described.

(11) Definite confirmation was obtained that well-known abnormalities of the vegetative growth characterised by multiple branching are produced by the feeding of *Antestia.*

(12) It is shown that the growth is stopped or much reduced by the feeding of *Antestia,* and when this is associated, as it usually is, with multiple branching, a "bunchy" or "matted" growth results, which increases pruning costs and much reduces the cropping ability of the tree.

(13) A short discussion follows which indicates certain practical conclusions that can be drawn from the above results.

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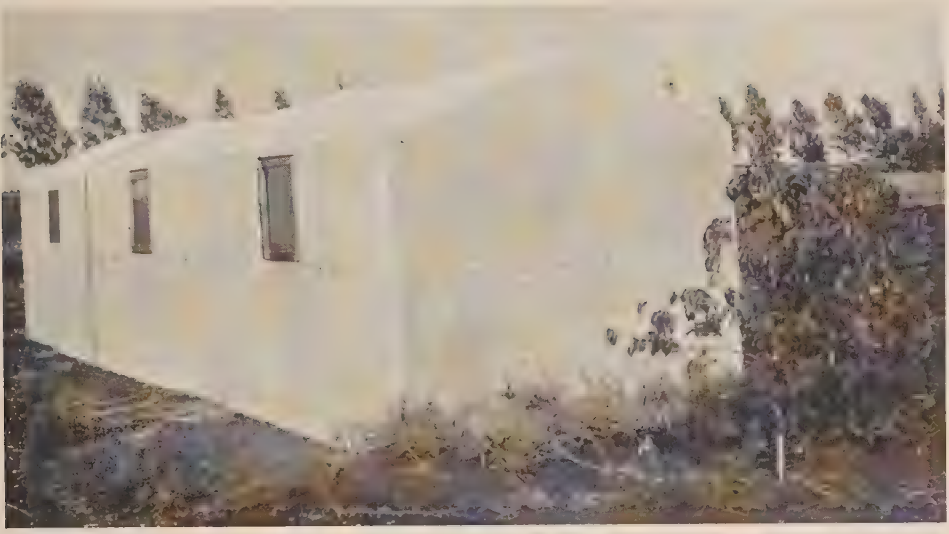

Fig. 1. Cage of three compartments enclosing three four-year old coffee trees. A similar tree is seen outside the cage.

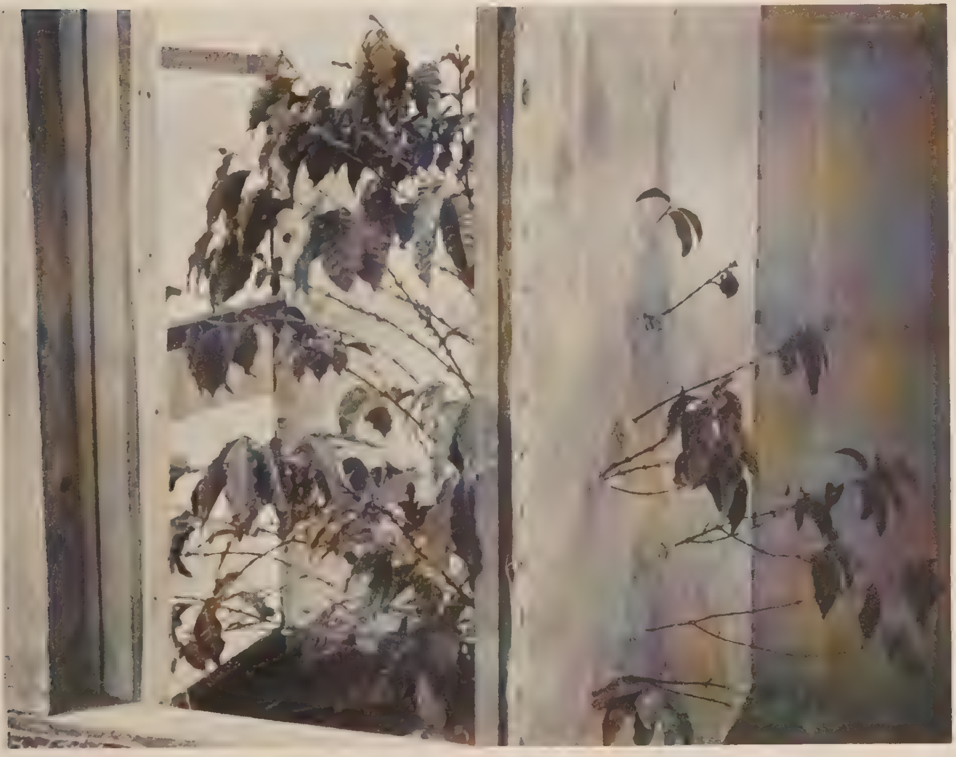

Fig. 2. The end compartment of cage, with cloth removed to show division in compartment. On left, main part of tree; on right, seven of the eight shoots are shown inserted through small sleeves in the cloth which are tied on cotton wool around the shoots.

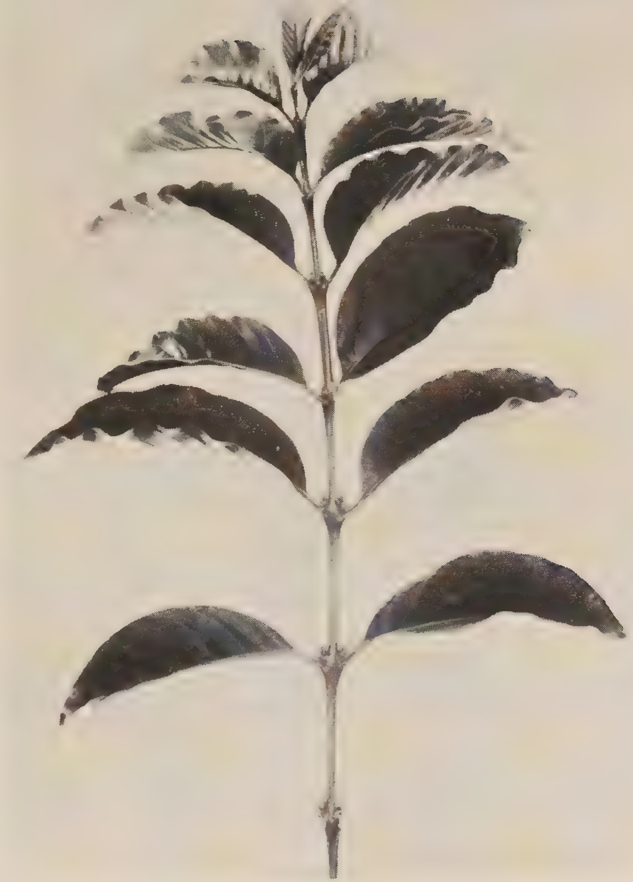

Fig. 1. A coffee shoot showing normal growth, with normal long internodes, healthy 'flower buds' and flower 'spike.'

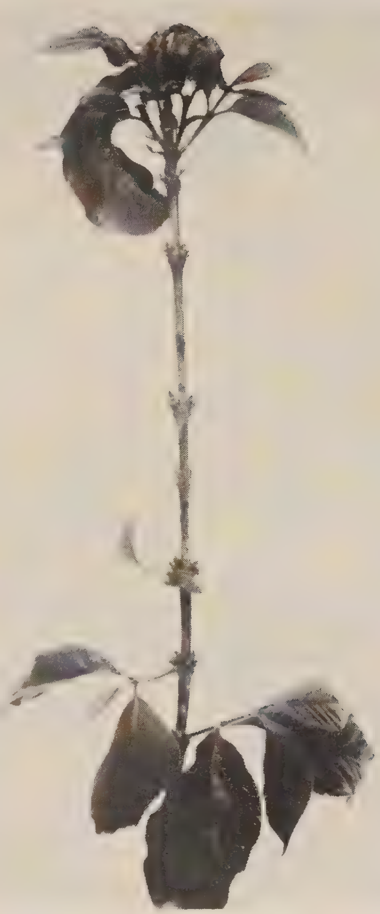

Fig. 2. A coffee shoot from cage I (see table IX) showing the result of *Antestia* feeding, shortened internodes near tip, multiple branching, distorted leaves and aborted flower buds.

THE MOSQUITO FAUNA AND CLIMATE OF NATIVE HUTS AT KISUMU, KENYA.

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CONTENTS.

PAGE
Introduction ... 91
Methods ... 92
Climate records ... 94
List of species of mosquitos met with ... 99
Night catches ... 101
Day catches ... 109
Influence of the human population in huts upon the mosquito population ... 116
Seasonal incidence of the principal species ... 126
Parasites of mosquitos ... 136
Attempts to mark individual mosquitos... 137
Summary ... 138
Acknowledgments ... 141
References ... 141

Introduction.

This paper is an account of work done at Kisumu, Nyanza Province, Kenya, between April 1940 and October 1941. It comprises a study of the Anopheline and Culicine population of native huts, together with an account of the climate of huts in relation to that of the outer air. The work was done during tenure of a Junior Fellowship for Research in Tropical Medicine under the Medical Research Council.

Kisumu, the administrative centre of the Nyanza Province, is situated on the shore of the Kavirondo Gulf, at its eastern extremity. The Gulf is a large arm of water running eastward from the northern part of Victoria Nyanza. The equator passes a few miles to the north of the town. Kisumu stands on the Kibuye Hills, a small range rising from a large plain formed by the gradual recession of the lake. This plain is surrounded by steep ranges, one of which, the Nandi Escarpment, passes just north of the town and is continued westward by the smaller Nyahera Hills. Rainfall in the hills is much greater than in the plains, and the water drains rapidly to the level country where it tends to accumulate and sometimes causes severe flooding. Large marshes exist in the plains and round the edge of the lake are very extensive papyrus swamps. Within the bounds of Kisumu these have been cleared during the last few years and a stone embankment has been built along the shore. Extensive filling has been necessary behind the embankment and is still in progress.

The country round Kisumu is open, with no large wooded areas. The dominant vegetation is a low scrub with thorn trees, and Euphorbias. There are some small plantations of Eucalyptus and bananas. The main crops are maize, millet, sweet potatoes, sugar and sisal.

In general, the climate of Kisumu is very equable. By day there is almost always a breeze from the lake and a land breeze springs up in the evening. The lake breeze carries water vapour to the surrounding hill ranges where cloud formation occurs. The clouds return with the evening land breeze and most of the rainfall occurs in the late afternoon or early evening. High winds are common at this time of day, and electric disturbances with thunder and lightning take place almost every evening. Line-squalls are frequently seen and many of the storms are of the circular type, occasionally accompanied by the formation of waterspouts or " dust devils." Temperature is largely dependent on rainfall and the coolest weather occurs during and after the long rains. The seasons are fairly well defined. There is a period of hot, dry weather from January till March. The long rains occur during April and May. From June till August there is a period of variable weather which may be cool or rather warm, depending on the rainfall. The short rains may occur any time between September and December, producing another spell of cool weather. Annual rainfall is about 35–40 ins.

The lake itself lies 3,720 feet above sea-level. It shows an annual rise during or after the long rains, this, of course, being dependent on the rainfall of a large part of East Africa. This rise varies greatly from year to year, and, according to Garnham (1929), follows an 11-year cycle closely correlated with the prevalence of sunspots. The Kavirondo Gulf, though almost 50 miles long, is extremely shallow, perhaps the greater part being only 10–12 feet deep. Its outlet to the main lake is very narrow. The result is that the lake breeze drives water into the gulf to produce a daily rise or false tide in the afternoon.

Within the municipal area of Kisumu active mosquito control is carried on, but this does not normally extend to the surrounding Central Kavirondo Native Reserve. The reserve is very densely populated. It is occupied by the Jaluo, a tribe of Nilotic negroes who depend mainly upon agriculture and fishing but who also possess large numbers of cattle, sheep and goats.

Malaria itself is outside the scope of this paper. It is by far the most serious medical problem of the Nyanza Province. For a full account, reference should be made to papers by Garnham (1929, 1935 and 1938). For present purposes it is enough to say that it is hyperendemic among Africans, and that it also affects severely the European and large Asiatic populations. Kisumu is a definite blackwater area. The dominant type of malaria is subtertian, but many cases of quartan occur among native children. Benign tertian and *Plasmodium ovale* malaria also occur but are of much less importance. Though the disease is hyperendemic among the stationary native population, severe seasonal exacerbations occur among immigrant and other susceptible groups. These are associated with periods when *Anopheles gambiae* is prevalent, while the endemic type appears to be maintained by *A. funestus*. These two mosquitos are the only known carriers in the area.

Methods.

In the Kisumu district almost all native huts are round buildings with mud walls and steeply pitched grass roofs. There is a space all round between the top of the wall and the roof. This is the main entry route for mosquitos. Deep overhanging eaves help to keep out rain. Windows are rare. The floor is usually of rammed earth. Practically every hut stands in the middle of a cleared space of earth or sand which is swept daily. There are two main types of hut, one with single and the other with double walls. In the former, cooking is usually done in a small separate kitchen, while in the latter it is often done between the walls. The Jaluo are on the whole a cleanly people. They are fond of bathing, and their huts, clothes and utensils are generally kept very clean. Well-kept huts are plastered every two or three months with a mixture of ant-hill earth and cowdung. In many cases small fires are kept glowing throughout the night inside the huts.

The first series of catches were made in such huts, but it soon became evident that a more critical method was desirable. Comparison between one hut and another was impossible, as no two were exactly alike. It therefore seemed expedient to build huts specially designed for mosquito catching. A suitable place was selected at Usoma, on the lake shore, just west of Kisumu airport and outside the mosquito control area. Preliminary catches here showed that mosquitos were prevalent at a season when they had already become scarce elsewhere. As this area is part of the native reserve, it was thought best to build near the house of a Jaluo elder and actually on his land, in order that he might look after the huts and prevent interference by natives. At first two huts were built and two more were added later. They were placed under a large fig tree, which gave some protection from rain, and near a high euphorbia hedge which acted as a wind-break. The nearest native hut (that of the elder mentioned above) was about 40 yards distant. The huts were situated about 100 yards from the landward edge of the papyrus swamp, which here forms a belt about 200 yards wide between land and open water. The huts were set about four feet apart with the eaves just touching. They were arranged in an open crescent, so that all might receive the same amount of shelter from the tree. All doors faced inward, towards the tree. The ground between the swamp and the building site was occupied by vegetable gardens with numerous irrigation furrows running in from the lake. The surrounding country is flat and open with low scrub and a few trees.

In designing such huts the following points seem important :—

1. The hut must approximate closely to the usual local type.

2. The catching boy must be able to reach every part with ease. One of the difficulties of catching in native huts is the fact that mosquitos are hard to locate in the grass thatch and that the higher parts are usually out of reach. If results are to be at all critical this difficulty must be overcome. In this case it was eliminated by making a ceiling from a single thickness of hessian.

3. If more than one hut is to be built a single design must be adhered to, in order to permit exact comparison.

4. Good doors with locks must be fitted, to prevent the entry of unauthorised natives.

5. The roofs must be steeply pitched to keep out rain. This is important if recording instruments are to be used.

Acting on these principles, huts were built to the specification given below. They proved very satisfactory in practice, and it is thought that this design, perhaps modified to suit local conditions, might prove useful in other areas.

Specification.—Round hut, internal diameter 11 ft. 6 in. Mud walls, 6 ft. high, on framework of vertical poles and horizontal zones of woven twigs. Vertical poles to reach 7 ft. above ground-level. No windows. Batten door 6 ft. by 3 ft. with combination padlock. Steeply pitched grass roof on framework of light poles, supported on tops of vertical wall poles. Ceiling—a single thickness of hessian stretched across tops of vertical wall poles (there is thus an open space 1 ft. high all round the top of the wall for mosquito entry). Eaves to project at least 2 ft. from wall and to reach within about 5 ft. 6 in. of ground. Rammed mud floor. Hut to be replastered every two months to prevent mud walls from cracking.

During previous work a technique of catching was evolved. It seemed satisfactory and was continued. One method of catching is to spread a white sheet on the floor, spray the hut with insecticide and pick up the dead mosquitos. Though rapid and efficient, this method was obviously unsuitable in the present case, as long series of catches were intended and it was thought that insecticide might soon make the hut untenable for mosquitos. Subsequent work with pyrethrum, not discussed in the present paper, has shown this to be the case. In any event it is an unsuitable method for night work when hourly catches are intended. Hand-catching was used throughout. In the writer's opinion it is a very good method if the catches be suitably standardised, the boy well trained and the hut carefully chosen. Supervision is essential. The methods were as follows :—The equipment consisted of a suction catching tube, chloroform and cotton wool, labelled tubes for killed mosquitos, and a 2-cell electric torch. The latter was of the type with a large reflector. The glass was covered with a sheet of greaseproof paper to dim and diffuse the light. Day catches lasted one hour, and were made from 7 to 8 a.m. Mosquitos caught on the ceiling, floor, walls and the outside of the walls, were placed in separate tubes. Night catches were made from dusk (7 p.m.) till dawn (6 a.m.) and consisted of 12 catches of 15 minutes each at intervals of one hour. Each catch began at a clock hour and an alarm clock was used for timing. The catching boy did not sleep in the hut where work was in progress. No fires were allowed, and the only light permitted was that carried by the catcher. Doors were kept closed by night, and by day the huts were empty and locked. For all routine and control work the population of the hut was one native. So far as possible, the same native slept every night in the same hut and the catches were made by the same boy. Throughout the year one hut was set aside as a control. It was also used for climate records, and the catches made in it were useful in studying the seasonal incidence of mosquitos. In this hut day catches were made on six days of the week, and a night catch on the 7th. In the last two months of the year night catches were made in one of the other huts, as a day catch was necessary in the control hut every morning. The other huts were used mainly for experiments on human population, etc. Though most of the work was done in huts, bush tents were occasionally used for special purposes.

Natives were employed to populate the huts. They were all small boys, 10–12 years old. They proved more satisfactory than adults for various reasons. Salaries were small—5s. to 7s. 6d. per month. This was quite important, as sometimes as many as 35 were employed at the same time. They were easily disciplined. They were all, of course, unmarried and were too young to wish to go off in the evenings to dances and beer-drinks. Every night they entered their huts at about 6 p.m., shortly before sunset. They left at 7 a.m. some time after sunrise.

Climate readings were made as follows :—A Stevenson screen and an 8 in. raingauge were set up in a suitable spot about 50 yards from the huts. Daily rainfall readings (mm.) were made at 8 a.m. and at the same time maximum and minimum temperatures (°C.) were read in the control hut and the screen. This was done every day throughout the year. For three consecutive months thermograph and hygrograph records were kept in hut and screen. The instruments were checked regularly by means of thermometers and the whirling hygrometer. In the hut, the thermometers were 3 ft. above the floor, the recording instruments 2ft. above the floor. Thermometer and whirling hygrometer readings were made hourly during the first few night catches.

Work in the huts lasted from October 1940–September 1941 inclusive. October was a good starting point as mosquitos were not numerous. Expenses were not high. Initially, the huts—including materials and labour—cost about £5 each. Each took about one week to build, representing approximately 1,500 man-hours.

Climate Records.

(*a*) *Temperature.*

At Kisumu, indoor and outdoor temperatures fluctuate comparatively little throughout the year, and there are no real extremes of heat or cold. This is shown by the daily readings of maximum and minimum thermometers in the control hut and Stevenson screen (Table I). Following the practice laid down by the Meteorological Office " Observer's Handbook," the readings are given in whole degrees.

TABLE I.

Maximum and Minimum Temperatures (°C.) in Hut and Screen.

	Absolute maximum	Absolute minimum	Absolute range	Mean maximum	Mean minimum	Mean range
Hut	33	17	16	27	20	7
Screen... ...	37	13	24	30	17	13

An important point is that the mean range of the hut is only about half that of the screen. Actually, every day the screen maximum was higher than the hut maximum and its minimum was lower than the hut minimum. Taking the whole year, the difference between the highest and lowest maxima in the hut was 10°C., in the screen 12°C. In the case of minima the differences were 7°C. and 8°C. respectively. Thus maxima fluctuate to a much greater extent than do minima.

In hot dry weather there is a big difference between indoor and outdoor temperatures. The highest difference recorded in one day between hut and screen maxima (6°C.), minima (6°C.), and ranges (10°C.), all occurred in such weather. Wet weather brings about a fall of both maxima and usually a rise of both minima—*i.e.* a diminution of both ranges. In such weather indoor and outdoor temperatures may be very similar. The smallest recorded differences between hut and screen maxima (1°C.), minima (1°C.), and ranges (3°C.), occurred in cool wet weather.

The form of the daily temperature curve was established by continuous thermograph records kept in hut and screen for three months (October–December 1940). The mean two-hourly figures for this period are given below (Table II).

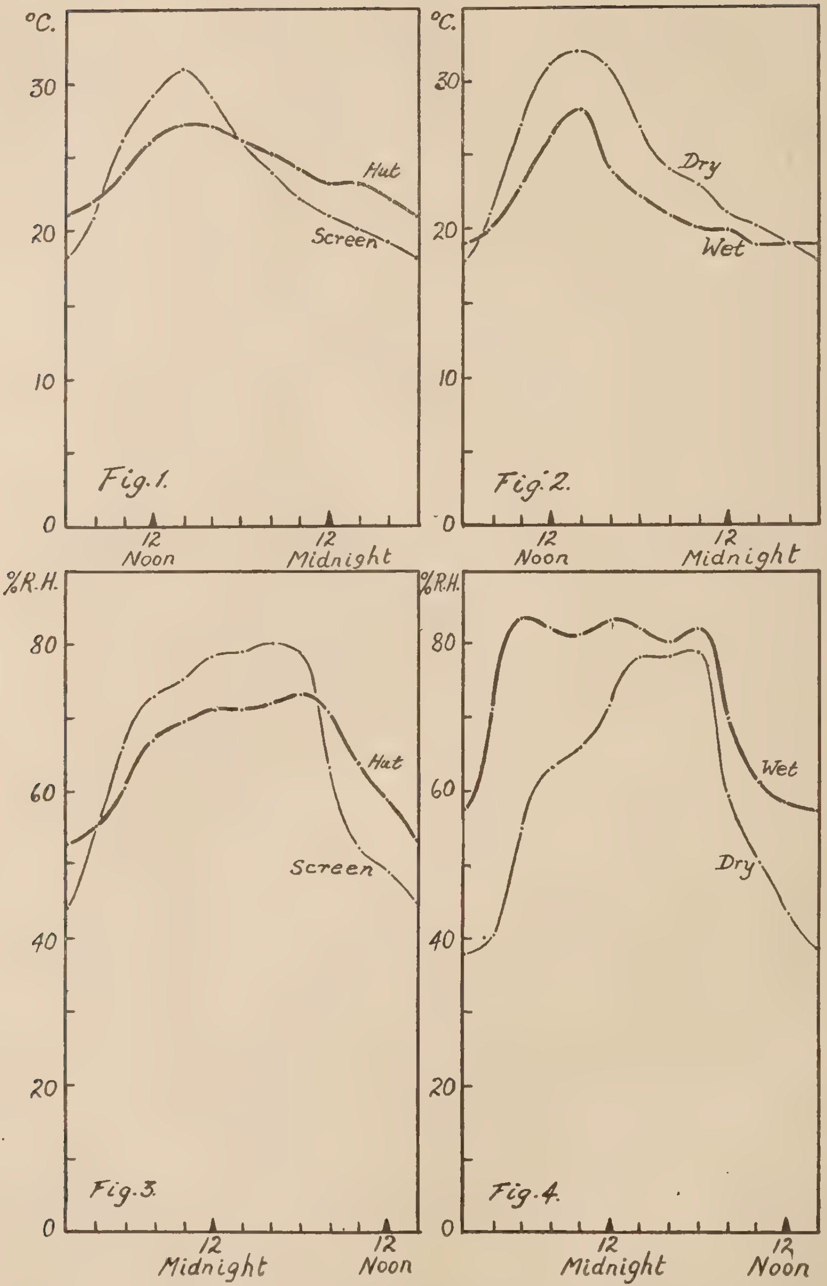
TABLE II.

Mean 2-hourly Temperatures, Hut and Screen Thermograph Records (°C.).

Hour	6	8	10	12 noon	2	4	6	8	10	12 night	2	4	Range
Hut	21	22	24	26	27	27	26	25	24	23	23	22	6
Screen ...	18	21	26	29	31	29	26	24	22	21	20	19	13

Thus the shade temperature maximum occurs at 2 p.m. In the hut there is some lag and the maximum occurs between 2 and 4 p.m. To show the curves clearly, the starting point for the graph (fig. 1) is at 6 a.m., when the minima are reached in both hut and screen. The graph shows clearly the equability of temperature in the hut.

As previously mentioned, the highest maxima, lowest minima and greatest ranges, occur in hot dry weather, and *vice versa*. In spite of this, nights in wet weather are really cooler than those in dry weather for the following reasons :—In hot dry weather the temperature falls slowly and evenly from 2 p.m. till 6 a.m. In wet weather the temperature falls much more abruptly in the late afternoon. Rainfall is usual at this time of day, and even if there is no actual rain the afternoon is generally cloudy. After this rapid drop the temperature forms a low " plateau " with a very slight decline to 6 a.m. Thus, while the actual minima at 6 a.m. are not so pronounced as in dry weather, the night as a whole is much cooler and the evening in wet weather is already as cool as late night in dry weather. For example, consider



Figs. 1–4.—(1) Mean 2-hourly temperatures in hut and Stevenson screen, from thermograph records; (2) mean 2-hourly temperatures in Stevenson screen in wet and dry weather, from thermograph records; (3) mean 2-hourly relative humidity in hut and Stevenson screen, from hygrograph records; (4) mean 2-hourly relative humidity in Stevenson screen in wet and dry weather, from hygrograph records.

the mean readings in the screen (Table III & fig. 2) for five consecutive wet days (19th–23rd November 1940) and five consecutive dry days (30th September–4th October 1940) :—

TABLE III.

Mean 2-hourly Temperatures in Screen in Wet and Dry Weather (°C.).

Hour	6	8	10	12 noon	2	4	6	8	10	12 night	2	4	Range
5 wet days ...	19	20	23	26	28	24	22	21	20	20	19	19	9
5 dry days ...	18	21	27	31	32	31	27	24	23	21	20	19	14

Thus, mosquitos resting in the hut are never exposed to sudden or marked changes of temperature, and they are not exposed to high temperatures by day (hut mean maximum=27°C.). In wet weather, when they are most numerous, there is a very equable temperature both indoors and outside during their period of nocturnal activity. With regard to the development of the malaria parasite in the mosquito it is interesting to consider the figures given by Grassi (1900). He states that the lowest temperature at which *P. falciparum* can develop continuously is 18°C. In the hut, the temperature fell below this level on 10 days only in the entire year, while in the screen lower levels were reached on 220 days—approximately 2 days in 3. The critical temperature for *P. vivax* is said to be 17·5°C. In the hut, minima lower than this level occurred on 7 days, in the screen on 185 days—about 1 day in 2. *P. malariae* is said to stop development at 16·5°C. The hut temperature never fell below this, but the screen temperature did on 108 days—almost 1 day in 3. It is known that if temperature is lowered beneath the critical level and is subsequently raised again, the parasite is able to continue its development. It is difficult to assess the importance of the numerous but short periods when the outside air fell to lower temperatures than the various levels concerned, but it seems clear that the hut is a more suitable environment for the development of the parasite. *A. gambiae* and *A. funestus*, the two carriers of malaria in Kisumu, both spend much of their time in houses by night and usually rest there by day. *A. coustani* and *A. pharoensis* are not uncommon and both enter houses, but so far dissection has shown no infection in these species at Kisumu. They enter, for the most part, during the early night and most leave before dawn. They are thus exposed to both outdoor minima and maxima.

(*b*) *Humidity.*

Hygrograph records were kept in the control hut and the screen during November and December 1940 (Table IV & fig. 3). The general form of the daily curves is the reverse of the temperature curves. The minimum relative humidity in both cases occurs at 2 p.m., and is taken as a convenient starting point for the graphs. *Note that these do not start at the same time of day as the temperature graphs.* From 2 to 8 p.m. there is a rapid rise, after which a high irregular "plateau" is maintained for most of the night. Once again the mean range in the hut is much smaller than that in the screen. The mean minimum for the hut is over 50 per cent.

TABLE IV.

Mean 2-hourly Humidity, Hut and Screen Hygrograph Records (% R.H.).

Hour	2	4	6	8	10	12 night	2	4	6	8	10	12 noon	Range
Hut	53	55	61	67	69	71	71	72	73	71	64	59	20
Screen ...	44	55	66	73	75	78	79	80	79	61	52	47	36

As in the case of temperature, there is an interesting comparison between wet and dry weather records. Wet weather shows a higher degree of saturation both by day and by night. In the early hours of the morning there is little difference. In wet weather there is a sharp rise of humidity from 2 to 6 p.m., after which a high and very even level is maintained till 6 a.m. The rapid afternoon rise is due to the fact that rainfall commonly occurs at this time of day. In dry weather the relative humidity begins to rise at the same time, but the ascent is much more gradual and goes on till after midnight, by which time the wet weather level has almost been attained. Table V shows the mean of the records in the screen for 5 consecutive wet days (20th–24th November 1940) and 5 consecutive dry days (16th–20th December 1940). Note the great difference in the ranges.

TABLE V.

Mean 2-hourly Humidity in Screen in Wet and Dry Weather (% R.H.).

Hour	2	4	6	8	10	12 night	2	4	6	8	10	12 noon	Range
5 wet days ...	57	71	83	82	81	83	82	80	82	68	61	58	26
5 dry days ...	38	40	55	63	66	72	78	78	79	59	50	43	41

During the first 3 months' work, whirling hygrometer readings were taken hourly during night catches (*i.e.* from 7 p.m. till 6 a.m.) both in the hut and outside. From these, coupled with thermometer readings, the saturation deficits were calculated. The mean deficits show a steady fall throughout the night in both cases. The deficit was always higher in the hut than outside. In the hut the mean deficit fell from 8·7 mm. at 7 p.m. to 5·1 mm. at 6 a.m. Outside it fell from 7·8 mm. at 7 p.m. to 3·8 mm. at 6 a.m. The ranges are thus almost the same, 3·6 and 4·0 mm. respectively.

The hygrograph records show that, as in the case of temperature, the hut is a very suitable day resting-place for mosquitos. Once again the main point is its extreme equability when compared with the outer air. In the heat of the day in dry weather the relative humidity in the screen often fell to about 20 per cent., while in the hut readings under 40 per cent. were rare. The most extreme records were obtained on 5th November 1940 when, at 5 p.m., the relative humidity in the screen fell to 7 per cent. with a temperature of 35°C. This represents a saturation deficit of approximately 39 mm. The corresponding readings in the hut were 25 per cent. R.H. at 30°C., with a deficit of about 22 mm. As these figures were obtained from recording instruments, they must be regarded as approximate only, but they demonstrate the high degree of protection given by the hut under such conditions to small insects, such as mosquitos, which are liable to desiccation. It should be remembered that the saturation deficit bears a close relationship to the drying power of the air and that the difference of 17 mm. between hut and screen is very high indeed. That the effects of such conditions on the metabolism and longevity of insects may be profound is shown in the excellent summary of the subject given by Wigglesworth (1939, chap. xiv).

(*c*) *The Effects of Human Population on the Climate of Huts.*

During one experiment 10 natives slept in one hut, and a comparison was made between its climate and that of the control hut with a single inhabitant.

On 3 nights hourly thermometer readings from 7 p.m. to 6 a.m. showed that the hut with 10 inhabitants was slightly warmer than the other. The natives entered at 6 p.m., and during the first two hours no difference was apparent. For the rest of the night the hut with 10 inhabitants was one or two degrees warmer than the control, the mean difference being just over 1°C. This was confirmed by a week's thermograph readings, which also showed that by day, when the huts were empty, their temperatures were almost identical. On two of these nights temperature readings were taken at the floor and ceiling of both huts, but no consistent difference was found in either case. Sometimes the floor was warmer, sometimes the ceiling. The differences were rarely as much as 1°C.

Hygrograph traces showed no consistent difference between the humidities of the huts either by night or by day. More careful readings with the whirling hygrometer were made simultaneously with the thermometer readings. These showed that, surprisingly, relative humidity was higher and saturation deficit lower in the hut with one inhabitant. The mean differences were 4 per cent. and 1·5 mm. respectively.

(*d*) *The Effect of Wind on Night Catches.*

A study of recording anemometer figures from Kisumu Airport showed that at night, wind velocities are usually very small, generally 1–3 metres per second. Strong winds did sometimes occur during the night, usually for short periods only. In such cases mosquito entry to the huts was diminished or even completely stopped while the wind lasted, as shown in the catch recorded in Table VI. The mosquito figures in this example include all species and both sexes. High wind blew from 9·30 till just after 11 p.m. Note that there is not any apparent accumulation of mosquitos during this period.

TABLE VI.

Effect of High Wind on a Night Catch.

Hour	7	8	9	10	11	12 night	1	2	3	4	5	6
Mosquitos caught ...	17	7	15	0	0	17	15	22	27	17	9	40

(*e*) *Rainfall and Lake Level.*

These will be discussed along with the seasonal incidence of *A. gambiae* and *A. funestus.*

List of Species of Mosquitos met with.

During work at Kisumu and in other areas, complete records were kept of all species of Anophelines and Culicines. In the following sections only the common and important species will be discussed in detail. A complete list of the species encountered is given below, with locality records and site of capture. Altitudes of the places mentioned are :—Kisumu, Maboko Island and Rusinga Island, about 3,700 feet ; Kaimosi Forest, about 5,000 feet ; Kitale district, about 6,200 feet ; Eldoret, about 6,800 feet ; Timboroa and Nyinabitaba (Ruwenzori), about 9,000 feet. The arrangement and nomenclature are those given by Edwards (1941). I am indebted to Mr. J. O. Harper for the identification of most of the scarcer Culicines.

Anopheles (*Anopheles*) *coustani*, Lav., v. *ziemanni*, Grünb.
Huts, tents and cowsheds, Kisumu and Maboko Island.

A. (*A.*) *symesi*, Edw.
Hut, Kisumu.

A. (*A.*) *implexus*, Theo.
Tent, Kaimosi Forest.

A. (*Myzomyia*) *natalensis*, H. & H., v. *multicinctus*, Edw.
Tents and river banks, Kaimosi Forest.

A. (*M.*) *nili*, Theo.
Hut, Kisumu.

A. (*M.*) *funestus*, Giles
Huts, tents and cowsheds, Kisumu and Maboko Islan

A. (*M.*) *keniensis*, Ev.
River bank, Kaimosi Forest.

A. (*M.*) *garnhami*, Edw.
Cowsheds, Eldoret. Larvae at Timboroa.

A. (*M.*) *christyi*, N. & C.
Tents and cowsheds, Eldoret and Timboroa.

A. (*M.*) *gambiae*, Giles
Huts, tents and cowsheds, Kisumu and Maboko Island.

A. (*M.*) *cinereus*, Theo.
Cowshed, Eldoret.

A. (*M.*) *maculipalpis*, Giles
Huts, Kisumu.

A. (*M.*) *pharoensis*, Theo.
Huts, tents and cowsheds, Kisumu and Rusinga Island.

Taeniorhynchus (*Coquillettidia*) *metallicus*, Theo.
Huts, Kisumu.

T. (*C.*) *fuscopennatus*, Theo.
Huts and tents, Kisumu and Maboko Island.

T. (*C.*) *aurites*, Theo.
Huts, Kisumu.

T. (*Mansonioides*) *africanus*, Theo.
Huts, tents and cowsheds, Kisumu, Maboko and Rusinga Islands.
Common in the open.

T. (*M.*) *africanus*, Theo., v. *nigerrimus*, Theo.
Huts, Kisumu.

T. (*M.*) *uniformis*, Theo.
Huts, tents and cowsheds, Kisumu, Maboko and Rusinga Islands.
Common in the open.

Aëdes (*Mucidus*) *scatophagoides*, Theo.
Huts, Kisumu.

A. (*Stegomyia*) *simpsoni*, Theo.
Huts, Kisumu.

A. (*S.*) *metallicus*, Edw.
Larvae in huts, Kisumu. Usually a tree-hole breeder.

A. (*Aëdimorphus*) *dentatus*, Theo.
Hut, Kisumu.

A. (*A.*) *cumminsi*, Theo.
Huts, tents and cowsheds, Eldoret, Kitale and Kaimosi Forest.

A. (*A.*) *hirsutus*, Theo.
Huts, Kisumu.

A. (*A.*) *ochraceus*, Theo.
Huts and tents, Kisumu.

A. (*Banksinella*) *lineatopennis*, Ludl.
Huts, Kisumu. Common in the open.

Culex (*Lutzia*) *tigripes*, Grp. & C.
Huts, Kisumu.

C. (*Culiciomyia*) *nebulosus*, Theo.
Huts, tents and cowsheds, Kisumu, Eldoret and Kaimosi Forest.

C. (*Culex*) *bitaeniorhynchus*, Giles
Hut, Kisumu.

C. (*C.*) *annulioris*, Theo.
Tent, Kaimosi Forest.

C. (*C.*) *duttoni*, Theo.
Hut, Kisumu.

C. (*C.*) *univittatus*, Theo.
Huts, tents and cowsheds, Kisumu, Eldoret and Kaimosi Forest.

C. (*C.*) *simpsoni*, Theo.
Tent, Kaimosi Forest.

C. (*C.*) *fatigans*, Wied.
Huts, Kisumu and Eldoret.

C. (*C.*) *vansomereni*, Edw.
Hut, Eldoret.

C. (*C.*) *hancocki*, Edw.
Larvae in bamboo stems, Timboroa and Nyinabitaba (Mobuku Valley, Ruwenzori).

C. (*C.*) *antennatus*, Beck. (=*laurenti*, Newst.)
Huts, tents and cowsheds, Kisumu.

C. (*C.*) *ingrami*, Edw.
Tent, Kaimosi Forest.

Night Catches.

(*a*) *Hourly Entry Figures.*

Only a few species were sufficiently numerous to warrant discussion under this heading. For the purpose of studying the entry curves only, series of catches made before the special huts were built have been included. The methods were the same in all cases and the addition makes the samples much larger.

Anopheles gambiae.

In the case of females, fairly large numbers are present in huts at 7 p.m. These are mainly insects which have entered for shelter after the morning catch or which have been missed during the catch. (This was demonstrated by making a series of 10 catches in which the hut was sprayed with insecticide about 2 hours before sunset. In this series the numbers caught at 7 p.m. were very small.) From 8 to 10 p.m. catches are small but show an upward trend. There is a marked increase at midnight, and from this time till dawn the numbers remain high. Between 5 and 6 a.m. there is another sharp rise, and the 6 a.m. catch is the highest of all. This is due to the entry, just before dawn, of large numbers of mosquitos seeking shelter for the day (Table VII & fig. 5). Thus, the night can be divided into 4 periods :—

(1) 7 p.m. Population mainly mosquitos which have been resting by day in the hut. Mean catch—2·5 females.

(2) 8–10 p.m. Short period of low entry. Mean catch per hour—1·5 females.

(3) 11 p.m.–5 a.m. Long period of high entry. Mean catch per hour—2·8 females. Note that the mean catch in this period is almost twice that of the preceding period.

(4) 6 a.m. Influx of mosquitos seeking shelter. Mean catch—4·1 females.

During a series of 26 catches in the control hut, records were kept of the numbers of fed and unfed females caught at each hour of the night. It was found that the total female catch and the numbers of fed females taken were closely related, and that their entry curves followed a very similar course (Table VII & fig. 9). The numbers of unfed females were much smaller and their entry curve apparently bore no relationship to the curve for total females. Their numbers fluctuated comparatively little from hour to hour. The correlation coefficients (r) were worked out and gave the following results :—

Fed and total females : r=+0·98 (highly significant).

Unfed and total females : r=+0·51 (not significant).

(In both cases the standard error × 2=0·6.)

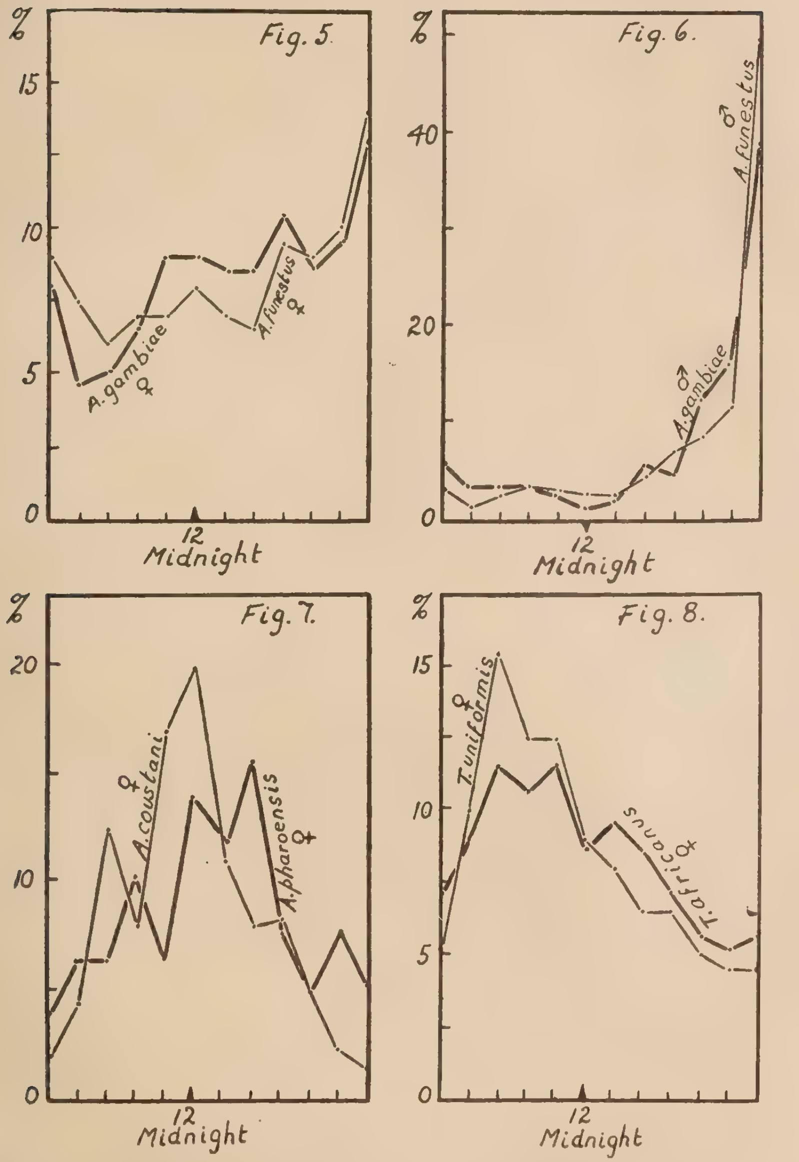
Thus the form of the entry curve is largely dependent on the numbers of fed females taken. This implies that the curve may give an indication of the degree of biting activity. It is interesting to note that Kerr (quoted by Evans, 1933) during all-night catches in the open, found that this species was most active from midnight onward, with a peak of biting activity from 2 to 4 a.m. It also seems likely that females remain in the hut after biting as, if they were to leave soon after doing so, it is improbable that such a large proportion of the catch would consist of fed specimens. Further evidence on this point will be discussed in the section comparing night with day catches.

TABLE VII.

Night catches of A. gambiae.

(In this and following tables percentages refer to percentages of the total catch and are correct to 0·5 per cent.)

Hour	7	8	9	10	11	12 night	1	2	3	4	5	6	Total
a. *Hourly entry in* 78 *night catches*													
Females ...	174	97	108	141	202	194	186	187	231	190	211	278	2,199
Percentage ...	8·0	4·5	5·0	6·5	9·0	9·0	8·5	8·5	10·5	8·5	9·5	13·0	
Males	7	4	4	4	3	1	2	6	5	14	18	46	114
Percentage ...	6·0	3·5	3·5	3·5	2·5	1·0	2·0	5·5	4·5	12·5	16·0	40·5	
b. *Total, fed and unfed, females in* 28 *night catches*													
Total	43	17	17	21	33	30	34	49	44	39	27	69	423
Fed	30	7	11	12	20	22	25	39	33	35	24	55	313
Unfed	13	10	6	9	13	8	9	10	11	4	3	14	110
c. *Females with group V ovaries in* 18 *night catches*													
Group V ...	14	4	1	2	3	0	1	3	1	1	2	11	43



Figs. 5–8. Entry curves of important species in night catches, hourly figures expressed as percentage of total catch: (5) female *A. gambiae*, total 2,199, and *A. funestus*, total 3,478; (6) male *A. gambiae*, total 114, and *A. funestus*, total 260; (7) female *A. pharoensis*, total 78, and *A. coustani*, total 229; (8) female *T. africanus*, total 1,072, and *T. uniformis*, total 2,401.

During a series of 18 catches in the control hut, ovary dissections of all females were made (Table VII). The total numbers are rather small and little information was gained. The only clear finding was in the case of ripe females with group V ovaries (see Christophers, 1936, chapter vi). By far the largest numbers of these were taken at 7 p.m. and 6 a.m. It is thus probable that most of these ripe females enter at or after dawn, those caught at 7 p.m. having rested in the hut by day.

The entry curve for males is very simple. Numbers are very small during most of the night. After 3 a.m. the catches begin to rise. A very marked increase occurs between 5 and 6 a.m. It thus appears that huts only become attractive to males in the dawn period, when they enter for shelter. It is also likely that they leave before 7 p.m., as the catch at this hour is quite low, unlike the catch of females at the same time (Table VII & fig. 6).

Anopheles funestus.

The entry curve for females is essentially similar to that for *A. gambiae.* Once again there is quite a large catch at 7 p.m., which does not occur if the hut is previously sprayed with insecticide. This is followed by a period of low entry from 8 p.m. to 2 a.m. A sharp rise then occurs and entry figures from 3 to 5 a.m. are high. Once again, the highest catch occurs at 6 a.m. (Table VIII & fig. 5). There are thus the same four periods as in the case of *A. gambiae,* but their time distribution is different. Note that the period of high entry begins 3 hours later than does that of *A. gambiae.* This confirms Garnham's (1938) finding that the entry of *A. funestus* to huts and tents took place from 2 a.m. till dawn, but disagrees with De Meillon's (1934) results. The latter are based on tent catches and show the peak entry at 11 p.m. The time distribution is as follows :—

(1) 7 p.m. Population mainly mosquitos which have rested in the hut by day. Mean catch—4·7 females.

(2) 8 p.m.–2 a.m. Long period of low entry. Mean catch per hour—3·1 females.

(3) 3–5 a.m. Short period of high entry. Mean catch per hour—4·2 females.

(4) 6 a.m. Influx of mosquitos seeking shelter. Mean catch—6·0 females.

During 26 catches in the control hut, records were kept of fed and unfed females. The results were similar to those for *A. gambiae.* Once again there was a high degree of correlation between fed and total females (Table VIII & fig. 10). In this case correlation does exist between unfed and total females, but the degree of significance is much lower than in the case of fed females. The results are :—

Fed and total females : $r=+0\cdot96$ (highly significant).

Unfed and total females : $r=+0\cdot79$ (significant).

(In both cases the standard error $\times$ $2=0\cdot6$.)

As in the case of *A. gambiae,* ovary dissections in a series of 18 catches gave little information. Once again, Group V females were commonest at 7 p.m., but in this case the 6 a.m. peak is not apparent (Table VIII).

The males behave almost exactly like those of *A. gambiae.* Catches are low till 2 a.m., after which a slow rise occurs till 5 a.m. There is a sharp peak at 6 a.m., representing half of the total (Table VIII & fig. 6). This is in agreement with De Meillon's (1934) results, in which the peak entry of males to tents occurred at 5 a.m. (No catches were made after this hour.)

TABLE VIII.

Night Catches of A. funestus.

Hour	7	8	9	10	11	12 night	1	2	3	4	5	6	Total
a. *Hourly entry in* 78 *night catches*													
Females ...	320	255	202	236	250	273	238	231	336	305	341	491	3,478
Percentage ...	9·0	7·5	6·0	7·0	7·0	8·0	7·0	6·5	9·5	9·0	10·0	14·0	
Males	8	4	7	9	8	7	6	12	18	22	30	129	260
Percentage ...	3·0	1·5	2·5	3·5	2·0	2·5	2·5	4·5	7·0	8·5	11·5	49·5	
b. *Total, fed and unfed, females in* 28 *night catches.*													
Total	29	6	7	21	24	9	16	7	15	22	18	27	201
Fed	24	4	5	17	15	6	12	6	13	17	15	20	154
Unfed	5	2	2	4	9	3	4	1	2	5	3	7	47
c. *Females with group V ovaries in* 18 *night catches*													
Group V ...	9	1	2	5	4	0	1	1	3	1	1	4	32

Anopheles coustani and *A. pharoensis.*

These species are rather scarce at Kisumu. It seems worth while to work out their entry curves, but the numbers are so small that it is necessary to include all night catches, including those made in tents and cowsheds. The numbers are still small and the results, of course, are less critical than in the case of *A. gambiae* and *A. funestus*, but the behaviour of the two species under consideration seems sufficiently well defined to justify their inclusion.

A. coustani females are scarce in the earlier part of the night, but the catches rise rapidly to a very marked peak from 11 p.m. till midnight (Table IX & fig. 7). After midnight the numbers fall steadily till 6 a.m. This finding is in agreement with that of Evans (1938), who describes a catch in a lighted tent in which the peak entry occurred from 11 p.m. till midnight.

A. pharoensis females behave similarly, but the maximum entry peak is not so well defined. It lasts from midnight till 2 a.m. (Table IX & fig. 7).

The males of these species cannot be discussed. No *A. coustani* males occurred in night catches and only one male *A. pharoensis* was taken.

TABLE IX.

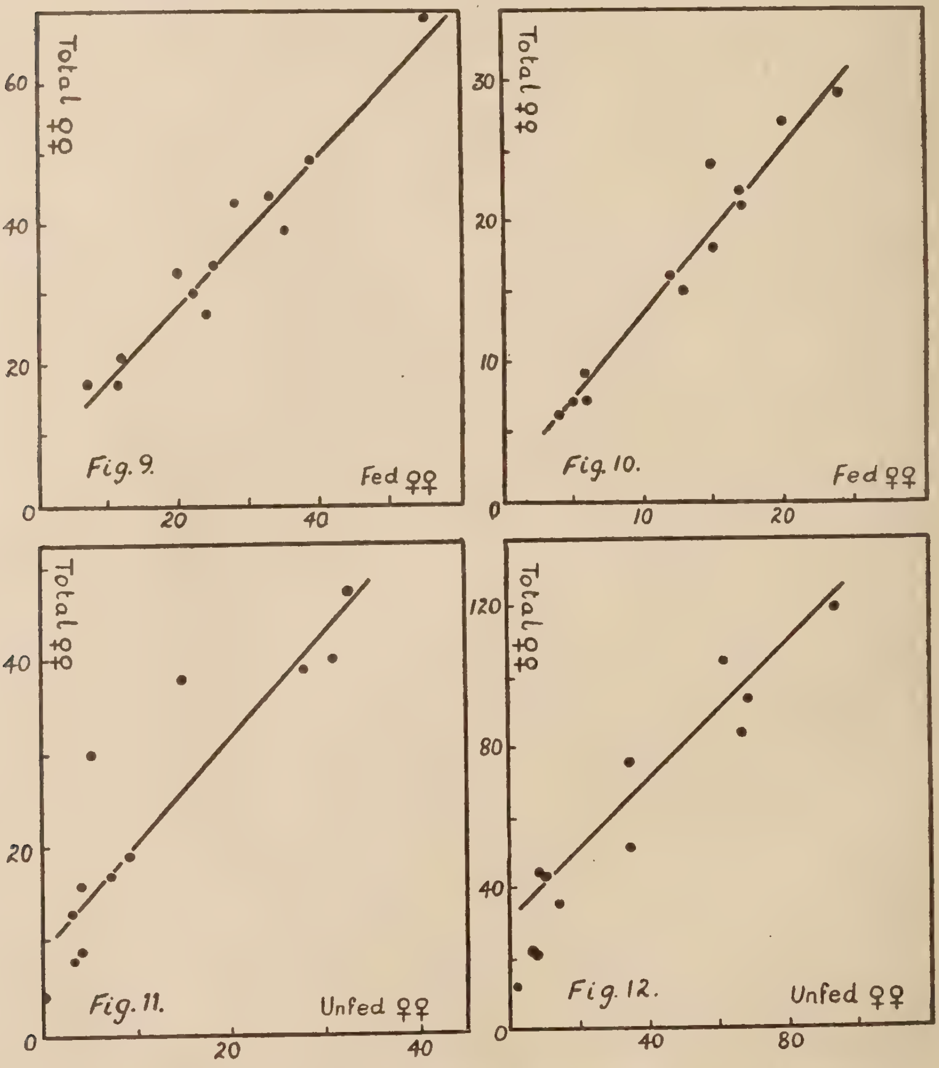
Entry of Female A. coustani *and* A. pharoensis *in* 100 *Night Catches.*

Hour	7	8	9	10	11	12 night	1	2	3	4	5	6	Total
A. coustani ...	4	10	29	18	39	46	25	18	19	12	6	3	229
Percentage ...	2·0	4·5	12·5	8·0	17·0	20·0	11·0	8·0	8·5	5·0	2·5	1·5	
A. pharoensis ...	3	5	5	8	5	11	9	12	6	4	6	4	78
Percentage ...	4·0	6·5	6·5	10·5	6·5	14·0	11·5	15·5	7·5	5·0	7·5	5·0	

Taeniorhynchus africanus and *T. uniformis*.

As these species were abundant in night catches, the same series will be considered as in the case of *A. gambiae* and *A. funestus*.

The behaviour of females is similar to that of *A. coustani* and *A. pharoensis*. Both are scarce at 7 p.m. but the catches rise rapidly. *T. uniformis* shows a very distinct peak at 9 p.m., *T. africanus* from 9 to 11 p.m. This is in agreement with Kerr's (1933) work in West Africa. After passing the peak period, catches of both species decline steadily till 6 a.m. (Tables X, XI & fig. 8).



Figs. 9–12.—Scatter diagrams of fed, unfed and total females of important species in night catches: (9) *A. gambiae*, fed females per hour catch plotted against total females for the corresponding catches; (10) *A. funestus*, fed females against total females, as above; (11) *T. africanus*, unfed females against total females, as above; (12) *T. uniformis*, unfed females against total females, as above.

In a series of catches in the control hut, records were kept of the numbers of fed and unfed females taken at each hour of the night (Tables X, XI & figs. 11, 12). The results are the reverse of those for *A. gambiae* and *A. funestus*, as in this case close correlation exists between the *unfed* and total females. The correlation coefficients are :—

Fed and total females : r=+0·60 (not significant).

Unfed and total females : r=+0·95 (highly significant).

(In both cases the standard error × 2=0·6.)

Both species feed by day in the open, but bite much more actively in huts by night. Thus the close relationship between unfed and total females probably implies that females leave the hut soon after biting. This point will be discussed further in the section comparing night and day catches.

TABLE X.

Night Catches of T. africanus *Females.*

Hour	7	8	9	10	11	12 night	1	2	3	4	5	6	Total
a. *Hourly entry in* 78 *night catches*													
Females ...	74	95	126	114	125	92	103	90	77	61	56	60	1,072
Percentage ...	7·0	9·0	11·5	10·5	11·5	8·5	9·5	8·5	7·0	5·5	5·0	5·5	
b. *Total, fed and unfed females in* 24 *night catches*													
Total	17	40	47	39	38	19	30	16	13	9	8	4	280
Fed	10	9	14	11	23	10	25	12	10	5	5	4	138
Unfed	7	31	33	28	15	9	5	4	3	4	3	0	142

TABLE XI.

Night Catches of T. uniformis.

Hour	7	8	9	10	11	12 night	1	2	3	4	5	6	Total
a. *Hourly entry in* 78 *night catches*													
Females ...	132	234	378	303	295	218	190	160	153	121	106	111	2,401
Percentage ...	5·5	10·0	15·5	12·5	12·5	9·0	8·0	6·5	6·5	5·0	4·5	4·5	
Males	0	12	32	20	14	18	20	8	8	2	4	4	142
Percentage ...	0·0	8·0	23·0	14·0	10·0	13·0	14·0	6·0	6·0	1·0	3·0	3·0	
b. *Total, fed and unfed females in* 24 *night catches*													
Total	51	83	119	93	104	75	44	35	43	22	21	12	702
Fed	16	16	25	24	42	40	35	21	32	15	13	10	289
Unfed	35	67	94	69	62	35	9	14	11	7	8	2	413

Certain catches were made to test the efficacy of mosquito creams. In these experiments one native was treated with the ointment, while another acted as a control. The method was to catch continuously, from dusk till dawn, all the mosquitos which actually alighted on the subjects. Large numbers of *Taeniorhynchus* were taken on the control in these tests and it was found that the peak of biting activity for *T. africanus* lasted from 9 to 10 p.m. That of *T. uniformis* was not clearly defined. In a catch made in the open the peak for both species was later and occurred at 11 p.m.

Males of *T. africanus* were very scarce—only 26 were taken. Those of *T. uniformis* show approximately the same entry curve as the females (Table XI).

The above section shows that the hours of maximum entry for the various species form a succession through the night (Table XII). The high incidence of *A. gambiae* and *A. funestus* at 7 p.m. is not considered, as it is not really due to entry.

TABLE XII.

Hours of Maximum Entry of important Species in Night Catches.

Hour ...	7	8	9	10	11	12 night	1	2	3	4	5	6
T. uniformis			++++									
T. africanus			++++	++++	++++							
A. coustani					++++	++++						
A. pharoensis						++++	++++	++++				
A. gambiae					++++	++++	++++	++++	++++	++++	++++	++++
A. funestus									++++	++++	++++	++++

(*b*) *Night Catches in Tents and in the Open.*

Night work was done in tents with the object of comparing the catch in dimly lighted and unlighted tents. Identical bush tents were pitched 20 yards apart, one unlighted and the other lighted by two candles. Each contained a single native. The catches were carried out in the usual way. One such catch was made on Maboko Island and one near the special huts. The results are here given as a total for the two nights (Table XIII).

TABLE XIII.

Night Catches in Lighted and Unlighted Tents.

Species	Dark			Light		
	Male	Female	Total	Male	Female	Total
A. gambiae	—	1	1	1	4	5
A. funestus	2	74	76	3	95	98
A. coustani	—	20	20	—	110	110
A. pharoensis	—	—	0	—	1	1
T. africanus	—	79	79	7	205	212
T. uniformis	1	47	48	8	324	332
C. nebulosus	—	22	22	—	1	1
Other Culicines	—	2	2	—	7	7

In the case of *A. gambiae* and *A. funestus* some difference exists between the catches, but the disparity is not very great and its significance is doubtful. *A. coustani* was caught in unusually large numbers as compared with hut catches and clearly preferred the lighted tent, as did also *T. africanus* and *T. uniformis*. *C. nebulosus*, on the other hand, showed an obvious preference for the dark tent.

Before the special huts were built, catches were made to investigate the endophily of *A. gambiae* and *A. funestus*. A catch was first made in a native hut near the lake shore. On the following night a catch was made in the open. A mosquito net was pitched about 50 yards from the hut and the writer sat inside it to act as a bait. A continuous catch was made of all mosquitos which alighted on the net between dusk and dawn. The results (Table XIV) demonstrate clearly that *A. gambiae* and *A. funestus* prefer to bite indoors, while *A. coustani*, *T. africanus* and *T. uniformis*, are very much more active in the open.

TABLE XIV.

Night Catches in a Hut and in a Mosquito Net pitched in the Open.

Species	Hut			Net		
	Male	Female	Total	Male	Female	Total
A. gambiae	—	12	12	—	—	0
A. funestus	18	129	147	—	2	2
A. coustani	—	2	2	—	9	9
A. pharoensis	—	—	0	—	1	1
T. africanus	—	5	5	12	280	292
T. uniformis	2	17	19	41	465	506
Other Culicines	—	1	1	—	7	7

Day Catches.

(*a*) *Comparison of Night and Day Catches.*

At this point it is convenient to consider the totals of the 53 night catches and the 320 day catches in the control hut (Table XV).

TABLE XV.

Totals of the Year's Night and Day Catches in the Control Hut.

	53 Night Catches			32 Day Catches		
	Male	Female	Total	Male	Female	Total
A. gambiae	78	974	1,052	1,168	4,008	5,176
A. funestus	145	1,311	1,456	4,391	9,003	13,394
A. coustani	—	37	37	—	—	0
A. pharoensis	1	26	27	—	55	55
T. africanus	8	508	516	1	188	189
T. uniformis	49	1,111	1,160	2	241	243
C. antennatus	5	20	25	66	282	348
Other spp.	8	37	45	30	58	88

As the numbers of night and day catches are widely different, comparison is best made by calculating the expected numbers per 10 catches in the case of the important species (Table XVI).

TABLE XVI.

Expected Numbers of important Species per ten Catches.

	Night Catches		Day Catches	
	Male	Female	Male	Female
A. gambiae	13	184	37	125
A. funestus	27	247	137	281
T. africanus	2	10	Under 1	6
T. uniformis	1	21	Under 1	8
C. antennatus	1	4	2	9

A study of the figures in the above tables shows that the various species may be divided into four groups :—

Group 1.

True house-haunting mosquitos which enter both for food and for shelter (*A. gambiae* and *A. funestus*).

Females are abundant both by day and by night. Males enter in large numbers at dawn to rest, and are common in huts by day only. Thus day catches, which include both sexes in large numbers, give the best estimate of the prevalence of these species.

The night entry curve for females of this group has the following characteristics :— There is a high catch of resting insects at sundown, a low incidence during the first part of the night, a high incidence during the latter part of the night and a peak at dawn, due to mosquitos entering for shelter. The form of the entry curve is closely correlated with the numbers of fed females taken.

Note that in the case of the females the difference between the expected numbers for night and day catches is not great. This supports the belief that the majority of females remain in the hut after biting. This will be discussed again in the section on analysis of day catches.

Group 2.

Mosquitos which enter huts mainly for feeding purposes (*T. africanus* and *T. uniformis* ; perhaps *A. coustani* and *A. pharoensis*).

This group is quite important. It should be remembered that in some areas *A. pharoensis* carries malaria, while *Taeniorhynchus* may have some connection with yellow fever and is known to be connected with Rift Valley fever and filariasis. Night catches are essential for an understanding of the group. Females are common in huts by night but not by day. Males are never common.

The entry curves of these species show a low incidence at sunset, a distinct peak during the first half of the night and a low incidence at dawn. The form of the night entry curve is correlated with the numbers of *unfed* females taken. The scarcity of females by day supports the contention that most leave the hut soon after biting.

Group 3.

Mosquitos which enter *human* habitations mainly for shelter (*Culex antennatus*).

This species is scanty in night catches, when it appears to enter in a casual fashion. Its incidence in human habitations is best gauged by day catches. (See also the section on analysis of day catches.)

Group 4.

Mosquitos which enter huts casually (mainly Culicines). Males and females of this unimportant group are scarce both by day and by night.

(*b*) *Analysis of Day Catches.*

During the period October 1940–May 1941, day catches were subjected to analysis by dissection, etc. The presence or absence of blood in the stomach was recorded for all important species. In the case of *A. gambiae* and *A. funestus*, ovary dissections were made and the wings were also inspected.

Wing grading (Table XVII) showed that the great majority of *A. gambiae* and *A. funestus* belonged to Grade 1, *i.e.* the wings and fringe were well marked and almost undamaged (see Christophers, 1936, chap. vi). This cannot be taken to imply that most of the mosquitos concerned were young. Females with Grade 1 wings showed ovaries in all stages of development, and on more than one occasion a female with Grade 1 wings was found to have one or two ripe eggs in an immature ovary, *i.e.* the ovary was developing for the second time.

TABLE XVII.

Results of Wing-grading A. gambiae *and* A. funestus ; *Day Catches in Control Hut.*

Wing Grade	1	2	3	4	Total
A. gambiae	1,696	16	0	1	1,713
A. funestus	1,040	11	3	0	1,054

Ovary dissections carried out during the same period gave rather disappointing results. In the case of both species, Group I was the commonest and Group V the next commonest. Periods of increase were marked by a rise in the percentage of females with Group I ovaries. In the case of *A. gambiae*, Group I represented 38 per cent. of all females at times of low incidence and 48 per cent. during increases. In the case of *A. funestus* Group I represented 26 per cent. during periods of scarcity and 41 per cent. during increases. Ovary dissections will be discussed again in the section analysing an *A. gambiae* increase.

More informative results were obtained from the records of the numbers of females containing blood (Table XVIII).

TABLE XVIII.

Numbers of fed and unfed Female Mosquitos taken in Day Catches in Control Hut.

	Fed	Unfed	Total
A. gambiae	1,323 (77%)	390	1,713
A. funestus	928 (88%)	126	1,054
T. africanus	115 (94%)	8	123
T. uniformis	177 (96%)	7	184
C. antennatus	13	84 (87%)	97

It is obvious that the great majority of *A. gambiae*, *A. funestus*, *T. africanus* and *T. uniformis* females were fed, *i.e.* these species feed actively in huts. On the other hand, most of the *C. antennatus* females were unfed, as this species enters huts mainly for shelter. The case of *A. gambiae* and *A. funestus* may be discussed further. Of the 390 unfed *A. gambiae*, 374, or 96 per cent., had Group I ovaries. Of the 126 unfed *A. funestus*, 108, or 86 per cent., had Group I ovaries. It is thought that Group I probably comprises mosquitos not more than 36–48 hours old, and it is known that in a second maturation of the ovary Group I does not occur again (Christophers, 1936). In addition, mosquitos do not feed for some time after emergence. It may thus be presumed that all unfed insects with Group I ovaries were young specimens which had never yet fed. Thus, excluding these newly emerged females, almost all the *A. gambiae* and *A. funestus* taken in day catches contained blood. If it be remembered that the numbers of females of these species taken in night and day catches are rather similar and that they are not attracted to a human bait in the open, it will be seen that this is additional evidence in favour of the view that females remain in the hut after biting.

A hypothetical account of the activities of female *A. gambiae* and *A. funestus* may now be put forward :—After emergence, at least some females rest in houses before their first blood meal. Older females bite by night, mainly in huts and mainly during the second half of the night. After feeding, they rest in the hut during the following day. Mature females with Group V ovaries are scarce in huts during most of the night, when they are presumably ovipositing, but enter in larger numbers at dawn for shelter (see section on night catches).

(*c*) *Analysis of an* A. gambiae *Increase by Dissection of Day Catches.*

The short rains of November 1940 were exceptionally heavy, almost 9 inches falling during the month. Much standing water was left after the rain and *A. gambiae* increased during December and January. As the increase was not unduly large, it was possible to dissect all the females taken in day catches and so to analyse the increase. Zero catches of females occurred in the control hut on 21st November and 13th February. These dates have been taken to mark the limits of the increase period. In the intervening period 70 day catches were made in the control hut. These are conveniently divided into 7 groups of 10 catches each (Table XIX). The numbers are not large enough for a separate consideration of each ovary group, so the females will be considered as follows :—

a. Unripe—Ovary Group I.

b. Ripening—Ovary Groups II, III and IV.

c. Ripe—Ovary Groups V and V+ (Group V+ includes females whose ovaries were found to be maturing for the second time).

It is obvious that the numbers of males and females in each group are correlated. The correlation coefficient (r)=+0·85. Twice the standard error=0·8, so the correlation is significant. It is also clear that correlation exists between the total female catches and the numbers of unripe females with ovaries in Group I (r=+0·95, and twice the standard error=0·8, so the result is significant). The marked similarity of the curves for males, females and females with Group I ovaries is shown in fig. 13.

If the numbers of unripe, ripening and ripe females be expressed as percentage of the total in each 10-catch period, it becomes obvious that the high incidence of *A. gambiae* was in this instance entirely dependent on the continuous supply of young females. The high percentage of young females was maintained till the last 10-catch period, when it dropped abruptly and the whole increase came to an end. This seems to imply that, during the season under consideration, the life of females was very short, as the population could not be maintained without the constant addition of young females.

TABLE XIX.

Analysis of an A. gambiae *Increase.*

10-catch period ...	1	2	3	4	5	6	7
Total males and females per period.							
Males	15	75	41	76	54	25	6
Females	43	180	127	157	152	69	50
Unripe, ripening and ripe females per period.							
Unripe	23	100	62	85	79	31	13
Ripening	14	36	29	35	44	23	24
Ripe	6	44	36	37	29	15	13
Unripe, ripening and ripe females as percentage of total females per period.							
Unripe	53·5	55·6	48·8	54·1	52·0	44·9	26·0
Ripening	32·6	20·0	22·9	22·3	28·9	33·3	48·0
Ripe	13·9	24·4	28·3	23·6	19·1	21·8	26·0

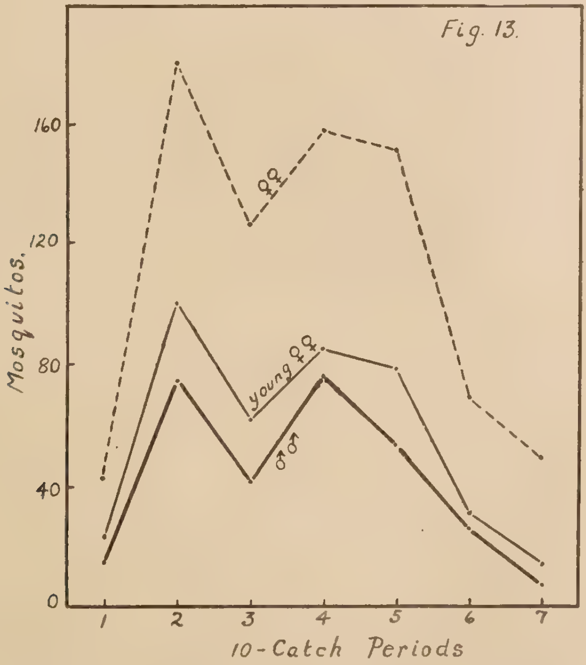


Fig. 13. Analysis of an *A. gambiae* increase; numbers of males, females and young females with Group I ovaries taken in successive 10-catch periods.

(*d*) *The Position of Resting Mosquitos in Day Catches.*

In 318 of the 320 day catches in the control hut, the catch was divided into mosquitos caught on floor, wall and ceiling (Table XX).

TABLE XX.

Position of Resting Mosquitos in a Hut.

	Floor			Walls			Ceiling		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
A. gambiae	—	—	0	32	455	487	1,136	3,551	4,687
A. funestus	—	—	0	195	846	1,041	4,185	8,053	12,238
A. pharoensis	—	—	0	—	3	3	—	52	52
T. africanus	—	2	2	—	112	112	1	69	70
T. uniformis	—	—	0	2	161	163	—	69	69
C. antennatus	—	3	3	21	89	110	44	185	229
Other spp.	1	1	2	6	12	18	23	45	68
Total			7			1,934			17,413

Thus, of a total of 19,354 mosquitos, 10 per cent. were caught on the wall and 90 per cent. on the ceiling. The insignificant number taken on the floor included no Anophelines. Gibbins (1933) found that *A. gambiae* and *A. funestus* were commonest on the upper wall and lower roof, but Garnham, working on *A. funestus* at Kisumu (1929), found that males were commonest on the walls and near the floor, while females were commonest on the roof. The present figures do not support Garnham's findings. Of 1,168 *A. gambiae* males, 3 per cent. were taken on the walls and 97 per cent. on the ceiling. Of 4,380 *A. funestus* males, 4 per cent. were taken on the walls and 96 per cent. on the ceiling. Of the 4,006 *A. gambiae* females, 11 per cent. were found on the walls and 89 per cent. on the ceiling. Of the 8,899 *A. funestus* females, 10 per cent. were on the walls and 90 per cent. on the ceiling. This shows how important the ceiling is in hand-catching. In a hut with a roof only, many would have been missed or out of reach. *C. antennatus* also showed a preference for the ceiling, but *Taeniorhynchus* spp. were commoner on the walls. The results were very consistent for every month in the year.

TABLE XXI.

Position of Mosquitos on the Wall of the Control Hut in Day Catches.

	Upper Half Wall	Lower Half Wall
A. gambiae	13	36
A. funestus	12	25
T. africanus	25	44
T. uniformis	54	69
C. antennatus	36	41
Other spp.	5	9
Total	145	224

During the 3 months October–December 1940 the catches on the wall were subdivided into mosquitos taken on the upper and lower halves of the wall (Table XXI). The results show that the lower and darker half was preferred by all species. In the case of *A. gambiae*, *T. africanus* and *T. uniformis*, most of the specimens were found within a foot of the floor.

In 301 of the day catches, a separate catch was made on the outside of the walls (Table XXII). Mosquitos were frequently found here, particularly in the upper part, which is in the shadow of the eaves. Of a total of 487 mosquitos caught in this series, 344 were males of *A. gambiae* and *A. funestus*. This represents 70 per cent. of the total (18 per cent. *A. gambiae* males and 52 per cent. *A. funestus* males).

TABLE XXII.

Day Catches on the Outside of the Walls of the Control Hut.

	Male	Female	Total
A. gambiae ...	90	28	118
A. funestus... ...	254	64	318
A. coustani... ...	—	1	1
T. africanus ...	—	4	4
T. uniformis ...	1	7	8
C. antennatus ...	8	15	23
Other spp.	4	11	15
Total	357	130	487

(*e*) *Experiments to determine the Best Hour for Day Catches.*

These experiments were done at the request of Colonel D. Bagster Wilson. They were carried out after the end of the year's work in the huts. Three huts were available, the control and huts *b* and *d*. Huts *b* and *d* had been used for work with pyrethrum powders, with the result that their mosquito population, as shown by day catches, was consistently lower than that of the control hut. Catches were made in series of 4, as follows :—

Series 1.

Preliminary. All huts caught at the same time (7–8 a.m.) to establish a normal comparison between their populations.

Series 2.

Control hut caught from 7–8 a.m., Hut *b* from 8–9 a.m., Hut *d* from 6–7 a.m.

Series 3.

Control hut caught from 7–8 a.m., Hut *b* from 9–10 a.m., Hut *d* from 10–11 a.m.

For the sake of brevity, catches are not here divided into species, only the totals being given (Table XXIII).

It is obvious that, between 6 a.m. and 11 a.m., the hour of search has little influence on the numbers of mosquitos caught. The results were subjected to the χ^2 test for goodness of fit. It was found that $\chi^2=0{\cdot}655$; n, the number of degrees of freedom in the table=4 ; therefore, P=more than 0·9. This implies that differences of the magnitude observed in these series may be expected to be due to chance in at least 9 cases out of 10—in other words, they have no significance. This result, it should be remembered, was obtained in huts with ceilings. It does not necessarily apply to ordinary huts, as in these, movements of the mosquitos up or down the grass roof might make them easier or more difficult of access at different hours. The above totals, however, give an indication of how consistent the results of hand-catching can be.

TABLE XXIII.

Results of Day Catching at Different Hours.

	Series 1	Series 2	Series 3
Control	64 (7–8 a.m.)	71 (7–8 a.m.)	86 (7–8 a.m.)
Hut *b*	36 (7–8 a.m.)	36 (8–9 a.m.)	44 (9–10 a.m.)
Hut *d*	49 (7–8 a.m.)	53 (6–7 a.m.)	73 (10–11 a.m.)
Results as percentage of catch in control hut.			
Control	100%	100%	100%
Hut *b*	56%	51%	51%
Hut *d*	77%	75%	84%

Influence of the Human Population in Huts upon the Mosquito Population.

(*a*) *Experiments with varying Numbers of Human Inhabitants.*

During December 1940–January 1941 preliminary experiments were carried out to find whether an increase in the number of occupants caused a corresponding increase in the mosquito population. At this time only two huts had been built, the control and one other. Three series of catches were made (Table XXIV). In each case 1 native slept in the control hut, while the other contained successively 10, 5 and 2 natives. Each series consisted of 10 day catches and 1 night catch.

TABLE XXIV.

Catches in Huts with varying Human Population.

a. *Comparison of hut with* 1 *native and hut with* 10 *natives.*

10 *day catches*

	1 native			10 natives		
	Male	Female	Total	Male	Female	Total
A. gambiae	58	142	200	61	734	795
A. funestus	4	19	23	9	161	170
A. pharoensis	—	—	0	—	11	11
T. africanus	—	3	3	—	94	94
T. uniformis	—	7	7	—	197	197
C. antennatus	—	2	2	—	3	3
Total			235			1,270

TABLE XXIV—*continued.*

1 *night catch*

A. gambiae	1	18	19	1	168	169
A. funestus	—	—	0	—	41	41
A. pharoensis	—	—	0	—	1	1
T. africanus	—	3	3	—	62	62
T. uniformis	—	5	5	3	238	241
C. antennatus	—	—	0	—	3	3
Other spp.	—	—	0	—	3	3
Total			27			520

b. *Comparison of hut with* 1 *native and hut with* 5 *natives.*

10 *day catches.*

	1 native			5 natives		
	Male	Female	Total	Male	Female	Total
A. gambiae	25	69	94	28	157	185
A. funestus	12	37	49	9	105	114
A. pharoensis	—	—	0	—	2	2
T. africanus	—	6	6	—	60	60
T. uniformis	—	6	6	—	99	99
C. antennatus	—	—	0	—	2	2
Other spp.	—	1	1	—	—	0
Total			156			462

1 *night catch*

A. gambiae	—	11	11	1	21	22
A. funestus	—	2	2	—	12	12
A. coustani	—	1	1	—	—	0
A. pharoensis	—	—	0	—	1	1
T. africanus	—	10	10	—	33	33
T. uniformis	—	28	28	—	93	93
C. antennatus	—	—	0	—	1	1
Total			52			162

TABLE XXIV—*continued.*

c. *Comparison of hut with* 1 *native and hut with* 2 *natives.*
10 *day catches*

	1 native			2 natives		
	Male	Female	Total	Male	Female	Total
A. gambiae	4	38	42	6	38	44
A. funestus	11	40	51	5	77	82
A. pharoensis	—	2	2	—	—	0
T. africanus	—	5	5	—	5	5
T. uniformis	—	1	1	—	8	8
C. antennatus	—	6	6	—	1	1
Other spp.	—	1	1	—	1	1
Total			108			141
1 *night catch*						
A. gambiae	—	18	18	—	14	14
A. funestus	—	12	12	—	11	11
A. coustani	—	4	4	—	—	0
A. pharoensis	—	1	1	—	1	1
T. africanus	—	5	5	—	26	26
T. uniformis	—	21	21	2	63	65
C. antennatus	—	—	0	—	1	1
Total			61			118

It was now apparent that the size of the human population had a profound effect on the mosquito population. Non-biting types, such as Anopheline males and *C. antennatus*, showed no preference for either hut. *A. gambiae*, *A. funestus* and *A. pharoensis* females showed a marked preference for the crowded hut in the experiments with 10 and 5 natives but did not, apparently, discriminate between 1 and 2 natives. It is true that, in the last experiment, *A. funestus* females were more abundant in the hut with 2 natives by day, but by night the numbers in the two huts were almost equal. *T. africanus* and *T. uniformis* chose the crowded hut in all three series, though in the comparison between 1 and 2 natives this was apparent in the night catch only.

The total catches in each series were as follows :—

a. 1 native—262. 10 natives—1,790. Ratio—1 : 6·8.
b. 1 native—208. 5 natives—624. Ratio—1 : 3·0.
c. 1 native—169. 2 natives—259. Ratio—1 : 1·5.

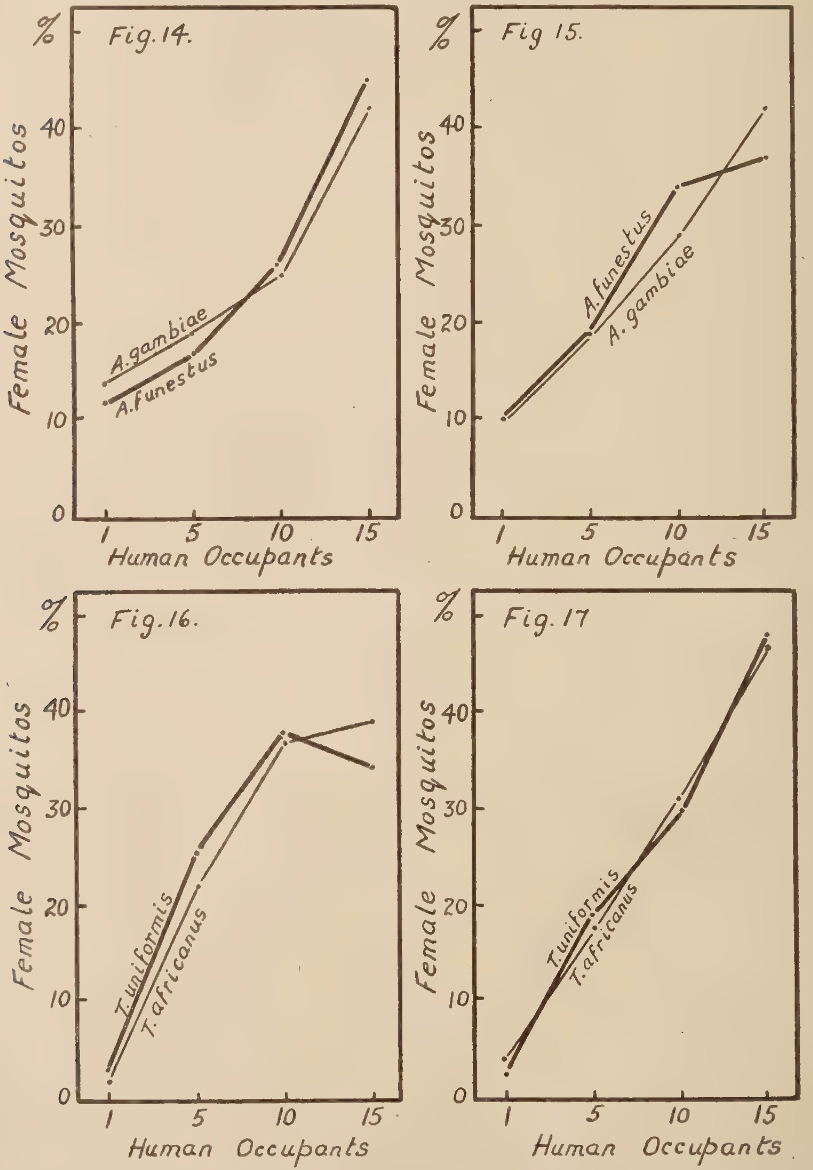
It thus seemed likely that a quantitative relationship existed between the human and mosquito populations of the huts. This could not be established finally, as the experiments had not been conducted simultaneously. Two more huts were built and a new series was begun. The control hut again had a population of 1 and the others contained 5, 10 and 15 natives respectively. The series consisted of 10 day catches and 2 night catches. The catches were made simultaneously in all 4 huts. The results are shown in Table XXV.

TABLE XXV.

Simultaneous Catches in four Huts with different Human Populations.

	1 native			5 natives			10 natives			15 natives		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
10 day catches.												
A. gambiae	35	239	274	32	325	357	37	436	473	75	741	816
A. funestus	85	228	313	72	334	406	88	488	576	205	855	1,060
A. pharoensis	—	2	2	—	7	7	—	10	10	—	11	11
T. africanus	—	6	6	—	70	70	1	119	120	—	123	123
T. uniformis	—	8	8	—	59	59	—	92	92	—	83	83
C. antennatus	1	—	1	—	2	2	—	1	1	—	—	0
Other spp.	—	1	1	—	1	1	—	—	0	—	—	0
Total ...			605			902			1,272			2,093
2 night catches.												
A. gambiae	1	54	55	1	104	105	5	161	166	5	237	242
A. funestus	7	73	80	8	138	146	12	252	264	18	269	287
A. coustani	—	1	1	—	1	1	—	5	5	—	4	4
A. pharoensis	—	—	0	—	5	5	—	4	4	—	9	9
T. africanus	—	10	10	2	47	49	—	82	82	—	121	121
T. uniformis	—	17	17	3	104	107	4	159	163	—	261	261
C. antennatus	—	1	1	—	1	1	—	—	0	—	14	14
Other spp....	—	—	0	—	2	2	—	4	4	—	6	6
Total ...			164			416			688			944

It is now obvious that a close numerical relationship exists between the human and mosquito populations of a hut. In the case of *A. gambiae, A. funestus* and *A. pharoensis* females the results are similar to those obtained in the first experiments. In the case of other species some differences may be observed :—Anopheline males seemed to prefer the hut with 15 inhabitants, as is shown by the day-catch records. In night catches, *C. antennatus* was also more prevalent in this hut, and *A. coustani* in the huts with 10 and 15 inhabitants. In day catches, *Taeniorhynchus* spp. did not appear to discriminate between the huts with 10 and 15 inhabitants. These species, as has been mentioned above, do not remain in huts in large numbers by day, and it seems that the preference limit was reached with a human population somewhere in the neighbourhood of 10. In night catches, however, they entered the hut with 15 occupants in much larger numbers than the hut with 10 occupants.



Figs. 14–17.—Night and day catches in huts with different numbers of human inhabitants; female mosquitos of important species, expressed as percentages of the total females of each species: (14) Day catches of female *A. gambiae* and *A. funestus*; (15) night catches of female *A. gambiae* and *A. funestus*; (16) day catches of female *T. africanus* and *T. uniformis*; (17) night catches of female *T. africanus* and *T. uniformis*.

For purposes of comparison, it is convenient to express the various catches of females of important species as percentage of the total catch of females of each species (Table XXVI & figs. 14–17).

TABLE XXVI.

Simultaneous Catches in four Huts with different Human Populations.
(Females of important species as percentage of total females of each species.)

No. of natives	Day Catches				Night Catches			
	1	5	10	15	1	5	10	15
A. gambiae % ...	14	19	25	42	10	19	29	42
A. funestus % ...	12	17	26	45	10	19	34	37
T. africanus % ...	2	22	37	39	4	18	31	47
T. uniformis % ...	3	25	38	34	3	19	30	48

Taking totals of all species for the entire series in each hut, the catches were 769, 1,318, 1,960 and 3,037. These figures are approximately of the order of 1 : 2 : 3 : 4—*i.e.* they form an arithmetical progression. It seems certain that a limit to the series must exist. In the hope of determining this level, an attempt was made to begin a new series, using higher numbers of occupants—1, 20, 25 and 30 per hut. This was unsuccessful, for a rather interesting reason. The small boys employed to sleep in the huts complained of the overwhelming numbers of mosquitos which entered when the huts were crowded, and refused to work at more than 15 per hut.

The above findings are obviously of practical significance. They imply that large communities, living at close quarters in malarious areas, are exposed to a high risk of infection. This, of course, applies to troops in camps and barracks, native labour encampments, native lines, prisons, etc. On the other hand, where large catches of mosquitos are required for experimental work, an increase of the human population of the huts concerned may be used to increase the mosquito population.

(*b*) *Experiments with Washed and Unwashed Children.*

It has already been shown that the climatic differences between huts with 1 and 10 inhabitants are not very great. It seemed unlikely that they could be responsible for the profound effects on the mosquito population described above. It appeared more probable that smell was the important factor. While adult Jaluo are very cleanly as a whole, the children are usually rather dirty. In the evening a large meal of maize, beans, etc., is taken. During the night, in a hut crowded with sleeping native children, the combined stench of sweat and flatus is almost overpowering. It is so nauseating that adult native catching boys are very unwilling to work in such huts by night.

It was decided that a comparison should be made between a hut with 5 washed and one with 5 unwashed children. As the comparison was to be made between the actual bodies of the two groups, all clothes and personal belongings were removed and the boys slept naked, each in a clean new blanket. The washed group were thoroughly scrubbed with soap and a brush just before sunset each evening. Ten day catches and two night catches were made in the series. At half-time the huts were changed, the unwashed group began to bathe and the other group stopped doing so. This was done to eliminate any differences in attractiveness between the huts or their inhabitants.

The results, shown in Table XXVII, demonstrate that the unwashed children were more attractive to the main species, *A. gambiae*, *A. funestus*, *A. pharoensis*, *T. africanus* and *T. uniformis*, while *C. antennatus*, as usual, showed no discrimination between the two groups. This leads to the belief that dried sweat probably acts as an attractant to biting species. It appears likely that an investigation of the attractant powers of the various constituents of sweat might lead to important results. Such work was impracticable in the present investigation.

TABLE XXVII.

Comparison between Catches made in Huts containing five washed and five unwashed Children respectively.

10 *day catches*

	Washed children			Unwashed children		
	Male	Female	Total	Male	Female	Total
A. gambiae	52	195	247	67	279	346
A. funestus	33	153	186	34	197	231
A. pharoensis	—	6	6	—	10	10
T. africanus	—	42	42	—	70	70
T. uniformis	—	27	27	—	51	51
C. antennatus	—	—	0	1	2	3
Total			508			711
2 *night catches*						
A. gambiae	4	72	76	11	122	133
A. funestus	1	45	46	4	86	90
A. coustani	—	1	1	—	—	0
A. pharoensis	—	—	0	—	4	4
T. africanus	1	30	31	1	55	56
T. uniformis	1	45	46	2	73	75
C. antennatus	—	2	2	—	2	2
Other spp.	—	1	1	—	3	3
Total			203			363

(*c*) *Experiments with Dirty Clothing.*

As a result of the above experiment, it was decided that further work should be done to find whether sweat attracted mosquitos. A trial was made to determine whether they could be attracted by unwashed clothing. Ten natives were employed. At this time there were two empty huts, *a* and *b*. On the first evening all clothes were taken from the children at sunset and were placed in hut *a*, hut *b* being left empty. A night catch was then made in the two huts. On the following evening the clothes were placed in hut *b*; hut *a* was left empty, and another night catch was made. The results of this series of two night catches (Table XXVIII) show that *A. gambiae* and *A. funestus* females were attracted by the clothes, but that other species, notably *Taeniorhynchus* spp., were not.

TABLE XXVIII.

Catches made to determine whether Mosquitos are attracted by Dirty Clothing.

2 *night catches*

	Empty hut			Hut with clothes		
	Male	Female	Total	Male	Female	Total
A. gambiae	—	33	33	4	63	67
A. funestus	—	33	33	4	137	141
A. coustani	—	1	1	—	1	1
A. pharoensis	—	1	1	—	1	1
T. africanus	—	13	13	—	17	17
T. uniformis	2	19	21	—	18	18
Other spp.	1	—	1	—	—	0
Total			103			245

(*d*) *Catches in Empty Huts.*

Apart from work in the special huts, three series of day catches, totalling 59, were made in empty native huts which had previously been occupied. In one of these huts a series of five night catches was also made. The results are shown in Table XXIX.

TABLE XXIX.

Catches in Empty Native Huts.

59 *day catches*

	Male	Female	Total
A. gambiae	27	50	77
A. funestus	10	59	69
C. antennatus	—	11	11
Other spp.	—	1	1
5 *night catches*			
A. gambiae	2	47	49
A. funestus	20	79	99
A. coustani	—	2	2
T. africanus	—	3	3
T. uniformis	—	2	2
Other spp.	—	10	10

Garnham (1929) states that at Kisumu an enormous influx of males occurs when a previously occupied hut is left empty. As the above figures did not appear to support this view, a more careful series of catches was made in the special huts, comparing the control hut (one inhabitant) with an empty hut which had previously been occupied. The series consisted of 17 day catches and 1 night catch. The results (Table XXX) showed that while the *proportion* of Anopheline males was increased, their actual numbers were not. In other words, the essential change in the population was a reduction in the numbers of the females of biting species.

TABLE XXX.

Comparison of a Hut with one Inhabitant and an Empty Hut.

17 *day catches*

	Occupied hut			Empty hut		
	Male	Female	Total	Male	Female	Total
A. gambiae	36	189	225	40	12	52
A. funestus	27	115	142	7	9	16
T. africanus	—	1	1	—	—	0
T. uniformis	—	2	2	1	—	1
C. antennatus	1	1	2	—	—	0
Other spp.	—	2	2	—	—	0
1 *night catch.*						
A. gambiae	2	22	24	4	5	9
A. funestus	1	10	11	2	3	5
A. pharoensis	—	1	1	—	—	0
T. africanus	—	3	3	—	—	0
T. uniformis	—	11	11	—	—	0

(*e*) *Catches made in a Subdivided Hut.*

The above sections deal with comparisons made between identical huts. It was thought that it would be worth while to investigate the possibility of using a single subdivided hut for similar experiments.

One of the experimental huts was divided in half by a single-thickness hessian curtain which extended to the top of the walls. Four series of two-day catches each were made, with different numbers of inhabitants on either side of the curtain. The results (Table XXXI) indicate that this method is reliable, at least where the numbers of inhabitants are not very large. As they do not differ much from those in the section comparing human populations, only the totals are tabulated here. In each series, the larger population slept on the first night on one side of the curtain and on the second night on the other side. This was thought necessary in case one side of the hut might form a better shelter for resting mosquitos than the other.

Thus in a case where comparative work is intended and, for one reason or another, huts cannot be built specially, an ordinary native hut can be selected and a hessian ceiling and partition fixed in about an hour. It is thought that it may be better to extend the hessian screen right to the ceiling instead of merely to the top of the wall. It has been found that this method is not very satisfactory where tests on repellents are to be carried out.

TABLE XXXI.

Series of two-day Catches each, in Hut subdivided by Hessian Screen, with different Numbers of Occupants on either Side

	Total catch
Half with 1 native	224
Half with 1 native	248
Half with 1 native	121
Half with 2 natives	389
Half empty	75
Half with 1 native	212
Half empty	248
Half with 3 natives	758

(*f*) *Catches comparing Huts with a Human Inhabitant and a Calf.*

This series, consisting of 10 day catches and 5 night catches, was done before the special huts were built. Two huts of very similar size and design were chosen. They were about 30 yards apart. One contained a single native, the other a calf. The results are shown in Table XXXII. The catches were made simultaneously.

TABLE XXXII.

Comparison of a Hut with one Native and a Hut with one Calf.

10 *day catches.*

	Native			Calf		
	Male	Female	Total	Male	Female	Total
A. gambiae	11	124	135	15	61	76
A. funestus	32	256	288	34	25	59
A. coustani	—	—	0	—	1	1
T. africanus	—	—	0	—	6	6
T. uniformis	—	1	1	—	2	2
C. antennatus	2	12	14	11	492	503
Other spp. (7)	—	2	2	9	17	26
5 *night catches.*						
A. gambiae	3	152	155	5	30	35
A. funestus	16	259	275	3	5	8
A. coustani	—	3	3	—	29	29
A. pharoensis	—	—	0	—	18	18
T. africanus	—	1	1	—	5	5
T. uniformis	—	1	1	—	9	9
C. antennatus	—	34	34	4	3,449	3,453
Other spp. (6)	—	—	0	1	22	23

These results show that female *A. gambiae* and *A. funestus* were more abundant in the hut containing the native, both by day and by night. *A. funestus* was much more markedly anthropophilic than *A. gambiae*. This confirms Garnham's previous work at Kisumu (1938). Garnham's figures are compared with those in the present series in Table XXXIII.

TABLE XXXIII.

Percentage of A. gambiae *and* A. funestus *Females in Huts occupied by Humans and Calves.*

	Total *A. gambiae* and *A. funestus* females	Percentage *A. gambiae*	Percentage *A. funestus*
Garnham 1938.			
Humans	1,112	23	77
Calves	428	63	37
Haddow 1940.			
Humans	791	35	65
Calves	121	75	25

These figures do not agree with the results of the extensive series of precipitin tests carried out in Kenya by Symes (1932) in which a much higher percentage of *A. gambiae* than *A. funestus* was positive for human blood. Symes' results showed that 80·4 per cent. of 1,449 *A. gambiae* were positive, as opposed to only 58·1 per cent. of 857 *A. funestus*.

The night catches in the present series demonstrated the distinct preference of *A. coustani* and *A. pharoensis* for the calf. This is in agreement with the work of Kauntze & Symes (1933) at Taveta, Kenya. A point of interest was the huge catch of *C. antennatus* in the calf hut, both by day and by night. By night it formed 96 per cent. and by day 75 per cent. of the total catch in the cowshed. This is strikingly different from the results obtained in the human habitation, where it formed only 7 per cent. of the night catch and 3 per cent. of the day catch. One Anopheline and several Culicines which were absent from the human habitation occurred in the calf hut. The heading " Other spp." includes, in the case of the calf hut, *Anopheles maculipalpis, Culex univittatus, C. duttoni, C. nebulosus, C. tigripes, Aëdes hirsutus, A. ochraceus* and *A. lineatopennis*. In the case of the human hut it includes only *Culex univittatus, C. tigripes* and *Aëdes dentatus*. The mosquito population of the human hut was predominantly Anopheline ; of a total of 909 mosquitos 94 per cent. were Anophelines. The case of the calf hut was almost exactly the reverse, as, of a total of 4,253 mosquitos, 95 per cent. were Culicines.

Seasonal Incidence of the Principal Species.

The seasonal incidence of mosquitos is best shown by the monthly totals for night and day catches in the control hut (Table XXXIV). It should be noted that the night and day catches show the same seasonal peaks. The night catches are included as they give better figures for *Taeniorhynchus* spp. and because *A. coustani* was never taken in day catches in this hut.

TABLE XXXIV.

Monthly Totals of Night and Day Catches in the Control Hut.

320 *day catches.*

		O	N	D	J	F	M	A	M	J	J	A	S
A. gambiae	m	1	11	163	117	14	153	60	382	227	22	4	14
	f	38	51	357	347	109	597	285	1,160	875	124	19	46
A. funestus	m	49	5	12	19	28	41	34	1,027	1,990	682	371	133
	f	256	42	38	81	109	122	179	1,347	3,941	1,515	968	364
A. pharoensis	f	1	—	—	—	2	—	1	4	4	1	29	13
T. africanus	m	—	—	—	—	—	—	—	—	—	—	1	—
	f	79	14	8	10	9	7	6	11	14	4	12	14
T. uniformis	m	—	2	—	—	—	—	—	—	—	—	—	—
	f	143	24	4	14	7	5	3	8	7	7	7	12
C. antennatus	m	6	5	13	—	—	1	1	3	1	3	6	27
	f	46	27	17	4	8	4	1	5	7	11	35	117
Other spp.	m	7	1	3	—	1	—	—	2	3	—	5	8
	f	5	2	5	1	1	5	2	2	1	3	11	20

53 *night catches*

		O	N	D	J	F	M	A	M	J	J	A	S
A. gambiae	m	—	5	13	1	1	23	2	19	13	1	—	—
	f	3	31	104	69	35	168	80	315	133	30	2	4
A. funestus	m	1	—	—	—	—	12	4	30	57	34	4	3
	f	19	8	10	7	18	42	41	314	451	201	154	46
A. coustani	f	—	—	1	1	4	1	1	10	15	1	3	—
A. pharoensis	m	—	—	—	—	—	—	—	—	—	—	1	—
	f	—	—	—	—	1	1	1	2	8	4	9	—
T. africanus	m	—	—	—	—	—	1	7	—	—	—	—	—
	f	111	52	40	28	29	49	21	40	44	25	24	45
T. uniformis	m	5	17	2	—	—	6	2	8	2	3	3	1
	f	340	127	65	66	51	93	52	78	80	41	65	53
C. antennatus	m	—	4	—	—	—	—	—	—	—	—	—	1
	f	—	4	2	—	—	2	—	1	1	3	4	3
Other spp.	m	—	3	—	—	—	2	—	—	1	—	—	2
	f	—	5	2	—	1	3	1	4	4	1	12	4

(*a*) *Anopheles gambiae.*

Near the extremities of its geographical range and at high altitudes, temperature may be an important limiting factor in the seasonal incidence of this species, as has been shown by Leeson (1931). In areas, however, where temperature is adequate for breeding throughout the year, *A. gambiae*, being almost entirely a puddle breeder, is largely dependent on local rainfall, except in places where residual pools in empty river-beds in the dry season provide a suitable breeding-ground. At Kisumu, *A. gambiae* is dependent on local rainfall.

In November 1940, abnormally heavy short rains of almost 9 inches produced a very large number of persistent pools. Breeding in these, *A. gambiae* began to

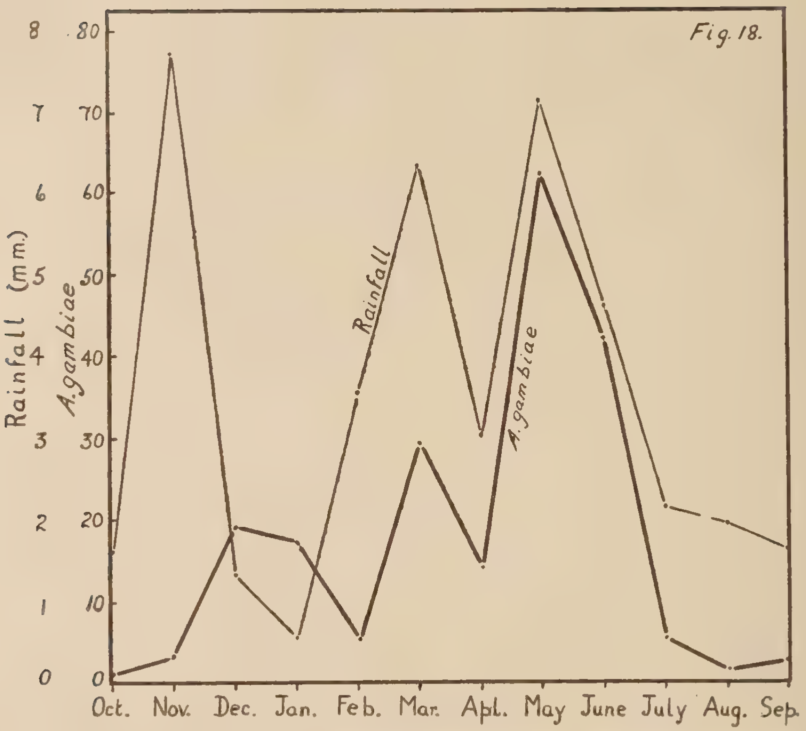


Fig. 18.—Mean daily catches of *A. gambiae* in control hut and mean daily rainfall (mm.) 1940–41.

TABLE XXXV.

Mean Day Catches of A. gambiae *in Control Hut and Mean Rainfall* (*mm.*), 1940–41.

	Mean *A. gambiae*	Mean rainfall
October, 1940 ...	1·4	1·6
November ,, ...	2·6	7·7
December ,, ...	19·3	1·3
January, 1941 ...	17·2	0·5
February ,, ...	5·1	3·5
March ,, ...	28·9	6·3
April ,, ...	13·7	3·0
May ,, ...	61·7	7·1
June ,, ...	42·4	4·6
July ,, ...	5·4	2·1
August ,, ...	0·7	1·9
September ,, ...	2·0	1·6

increase at the end of the month and was able to maintain a fairly high population during December and January. In March the long rains began and another increase took place. In April the rainfall was much decreased and the *A. gambiae* population diminished. In May heavy rain again occurred and another increase took place. Thus, in the year, there were three main rainy periods and each of these was associated with an *A. gambiae* increase (Table XXXV & fig. 18).

It was at first thought that correlation between monthly rainfall and monthly catches of *A. gambiae* would be well marked. When, however, the figures were worked out it was found that r was only +0·4, while twice the standard error was 0·6. Thus, the coefficient of correlation was below the significant level. The seasonal incidence of *A. gambiae* is obviously connected with rainfall, but this calculation implied that the relationship was not quantitative to a significant degree. The reasons for the absence of correlation were, apparently, the time-lag of the December–January increase and the fact that the size of the population during an increase was not proportional to the *amount* of rain which had fallen.

It thus seemed that the connection between *A. gambiae* and rainfall was qualitative rather than quantitative. It was noted that in April 1941, while both rainfall and *A. gambiae* decreased, rainfall was still quite substantial. This led to the conclusion that perhaps a certain threshold value for rainfall had to be passed before a definite increase could occur. In order to test this hypothesis, the Kisumu Health Office records for the last 9 years were consulted and the monthly figures for *A. gambiae* and rainfall were noted. It was found that during this period 18 main increases had occurred. In the case of 16 of these the associated rainfall had been 5 inches or more per month. In the case of the other two the rainfall was 4·8 and 3·5 inches respectively. It was also found that an increase might occur in the same month as the heavy rainfall or in the succeeding month. If a rainfall of 5 inches or over was maintained for several months, the *A. gambiae* population continued to increase. If, on the other hand, the rainfall diminished after the first population increase, a total of 3 inches or over in succeeding months was usually adequate to maintain the population at a high level, but without further increase. Thus, at Kisumu, the minimum rainfall value which will permit an increase of *A. gambiae* to take place appears to be 5 inches or about 125 mm. per month, but the increased population may often be maintained at a high stationary level by a fall in succeeding months of at least 3 inches or 75 mm. Mr. F. Hewitt, Senior Health Inspector, has for some time regarded a rainfall of 6 inches per month as the danger level for Kisumu. When this figure has been attained, all seepages begin to flow and the land becomes saturated.

It seemed important to try to establish which factor was responsible for the size of the *A. gambiae* population during periods of increase. The 1940–41 records (fig. 18) showed three periods of increase. In November the population was very small, and in December a moderate increase took place. A higher initial population in February yielded a more marked increase in March. A still higher initial population in April gave the largest increase of the year in May. It thus seemed possible that there was an approximate quantitative relationship between the population during the first month of an increase and the lower initial population of the preceding month. Two sets of data were used to test the validity of this theory, the writer's figures for 1940–41 and the Kisumu Health Office figures for 1940–41, compiled by Mr. J. O. Harper. The writer's records comprise the night and day catches in the control hut and day catches made during a routine survey of several huts at Usoma during the earlier months of 1941. These are referred to below as huts 1–8. Mr. Harper's figures cover the routine day catches in the 7 catching stations of the Kisumu area. As the Health Office catches and those made in huts 1–8 were of much shorter duration than those in the control hut, the figures per catch were much smaller. Monthly totals could not be used as the numbers of catches varied from month to month in both

TABLE XXXVI.

A. gambiae *Population per ten Catches in successive Months during Periods of Increase,* 1940–41.
Health Office figures in italics.

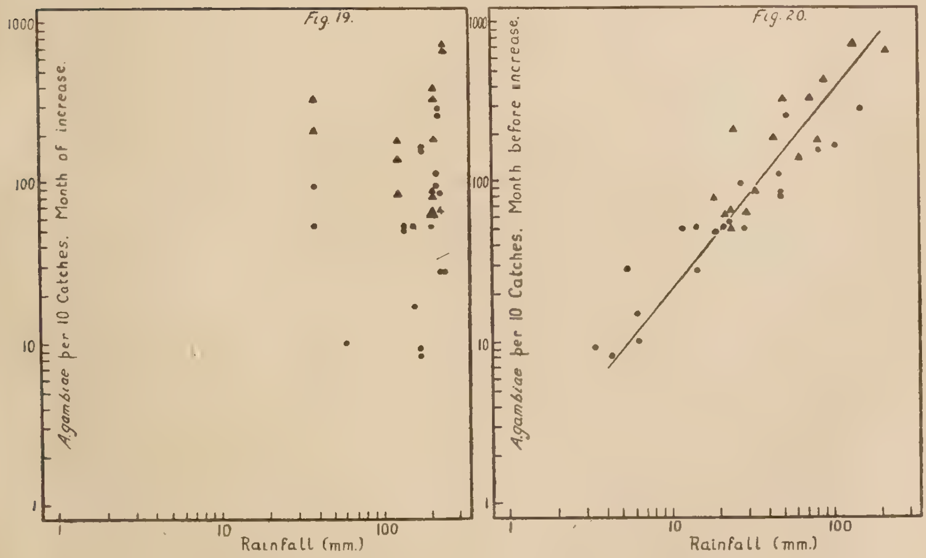
	First month, initial population		Second month, increased population	
Station 2, 1940	*March*	*4*	*April*	*10*
Station 1, 1940	*March*	*5*	*April*	*9*
Station 6, 1940	*October*	*6*	*November*	*29*
Station 4, 1940	*May*	*7*	*June*	*11*
Station 5, 1941	*March*	*7*	*April*	*16*
Station 7, 1941	*March*	*13*	*April*	*50*
Station 5, 1941	*April*	*16*	*May*	*28*
Station 5, 1940	*November*	*16*	*December*	*53*
Hut 4, 1941	February	20	March	75
Station 5, 1940	*January*	*21*	*February*	*48*
Station 6, 1941	*February*	*23*	*March*	*51*
Hut 6, 1941	February	23	March	60
Hut 7, 1941	February	24	March	55
Hut 1, 1941	February	25	March	51
Hut 2, 1941	February	25	March	63
Control, day, 1940	November	26	December	193
Station 6, 1940	*November*	*29*	*December*	*92*
Station 6, 1941	*January*	*30*	*February*	*50*
Hut 5, 1941	February	31	March	62
Hut 3, 1941	February	35	March	84
Hut 8, 1941	February	45	March	168
Station 5, 1940	*February*	*48*	*March*	*105*
Station 7, 1941	*April*	*50*	*May*	*79*
Station 6, 1940	*January*	50	*February*	81
Hut 1, 1941	March	51	April	82
Control, day, 1941	February	51	March	289
Station 7, 1940	*February*	*54*	*March*	231
Hut 2, 1941	March	63	April	128
Control, night, 1940	November	72	December	293
Station 6, 1940	*March*	*81*	*April*	*145*
Hut 3, 1941	March	84	April	162
Control, night, 1941	February	90	March	382
Station 5, 1940	*March*	*105*	*April*	*152*
Control, day, 1941	April	133	May	617
Station 6, 1940	*April*	*145*	*May*	*253*
Control, night, 1941	April	205	May	558

sets of data. It was found convenient to use, as a working unit, the expected number of *A. gambiae* per 10 catches. Only distinct increases were considered, and cases where the initial population was very low (less than 4 per 10 catches) were eliminated. It should be explained that the rainfall at Kisumu is extremely local—a fall of an inch may be recorded in one part of the area while in others no rain has occurred. The result is that an increase does not always begin in all areas in the same month. The figures are given in Table XXXVI and the rainfall of the months of increase in Table XXXVII.

TABLE XXXVII.

Rainfall (mm.) during the Months of Increase listed in the Second Column of Table XXXVI.

February 1940 ...	134·5 mm.
March 1940 ...	205·5 mm.
April 1940 ...	165·0 mm.
May 1940 ...	202·8 mm.
June 1940	62·3 mm.
November 1940 ...	229·9 mm.
December 1940 ...	40·0 mm.
March 1941 ...	195·1 mm.
May 1941	220·2 mm.



Figs. 19–20.—(19) Scatter diagram showing absence of correlation between *A. gambiae* during months of increase (expected numbers per 10 catches) and the rainfall of the same months, 1940–41. J. O. Harper's figures—circles ; author's figures—triangles. Doubly logarithmic scale for the sake of compactness ; (20) Scatter diagram showing correlation between *A. gambiae* populations preceding and during increases, 1940–41. Expected numbers per 10 catches. J. O. Harper's figures—circles. Author's figures—triangles. Doubly logarithmic scale for the sake of compactness.

If the *A. gambiae* figures for each of these months of increase (*i.e.* the second figure of each pair in Table XXXVI) is plotted against the rainfall for the corresponding month (fig. 19), it is obvious that no correlation exists between the mosquito population and the *amount* of rain which has fallen during the month.

If, on the other hand, the initial and increased populations listed in Table XXXVI are plotted one against the other (fig. 20), it is seen that a high degree of correlation exists. Working out the figures, it is found that r=+0·85 and that twice the standard error=0·34, a highly significant result. It is true that the figures in the table do not form a perfect series, but it should be remembered that they are derived from catches made by many different natives, using varying methods, in a number of separate areas. For example, the proportional increases recorded in the control hut are much more pronounced than in any of the other stations. This is probably due to the fact that catching in this hut was more careful than in the case of the others, and that the time available for catching was much longer. This allowed for a fairly complete catch, even when mosquitos were very numerous.

Of the increases listed, 8 continued for several months. In such cases each month has been plotted against the succeeding month, February against March, March against April, etc. These figures fit in well with the others, as is shown by fig. 20. In all of these 8 the population increased over a period of at least 3 months. Considering the month in which the peak was attained and the preceding 2 months, the following figures are obtained :—

	1st month	2nd month	3rd (peak) month
Mean catch	30	68	122

These figures are in the ratio of 1·0 : 2·3 : 4·1—*i.e.* they form, approximately, a geometric series. The Health Office figures for the last 9 years show 11 periods of increase which were similarly prolonged. The results in this case are :—

	1st month	2nd month	3rd (peak) month
Mean catch	70	182	456

The results are very similar to the 1940–41 catches, the figures being in the ratio of 1·0 : 2·6 : 5·2. Buxton (1939) has discussed in some detail the growth of louse populations. He points out that, as in the case of other animals and plants, increase is at first on a geometrical ratio. Subsequently, the pressure of the environment reduces the rate of increase till a point is reached at which no further increase takes place. He states that the point at which the pressure begins to be effective is unknown but that it probably varies from case to case. Almost certainly this principle applies to *A. gambiae*, and once again the limit to increase is unknown and probably variable.

To sum up :—At Kisumu, *A. gambiae* is dependent on local rainfall and a minimum of 5 inches per month is necessary before a definite increase takes place. When an increase does occur, the population in the first month will be proportional, not to the amount of rain which has fallen, but to the size of the population in the month preceding the increase. If, in succeeding months, the population is enabled to increase further by favourable environmental conditions, it will do so in geometric ratio.

It is thought that an application of these principles may help in the prediction of *A. gambiae* increases and, where infectivity figures and similar epidemiological data are available, they may be of assistance in the forecasting of malaria epidemics. While it seems likely that the mechanism of the actual population increase may be generally applicable, it is certain that the threshold value for rainfall must vary greatly in different areas.

The seasonal incidence of males of *A. gambiae* was similar to that of females, both in night and in day catches, and the number of males taken in huts was proportional to the number of females. Comparing the monthly totals for males and females taken in day catches in the control hut (fig. 21), correlation was found to be well marked. The coefficient of correlation, r, was +0·87, while twice the standard error was=0·6. This is in agreement with work in Nyasaland by Lamborn (1925).

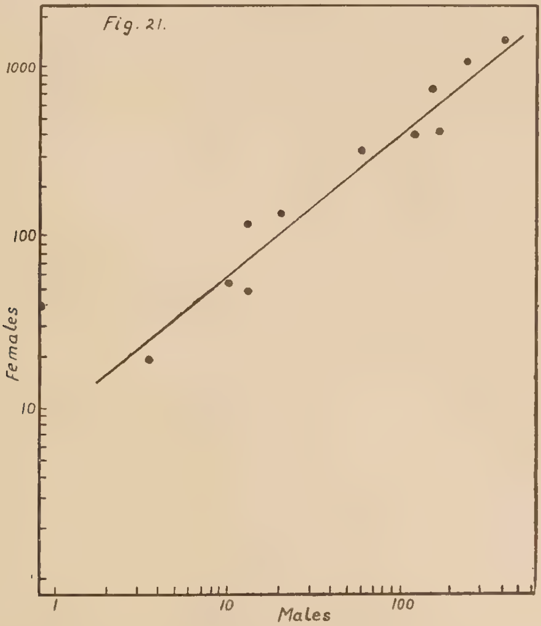


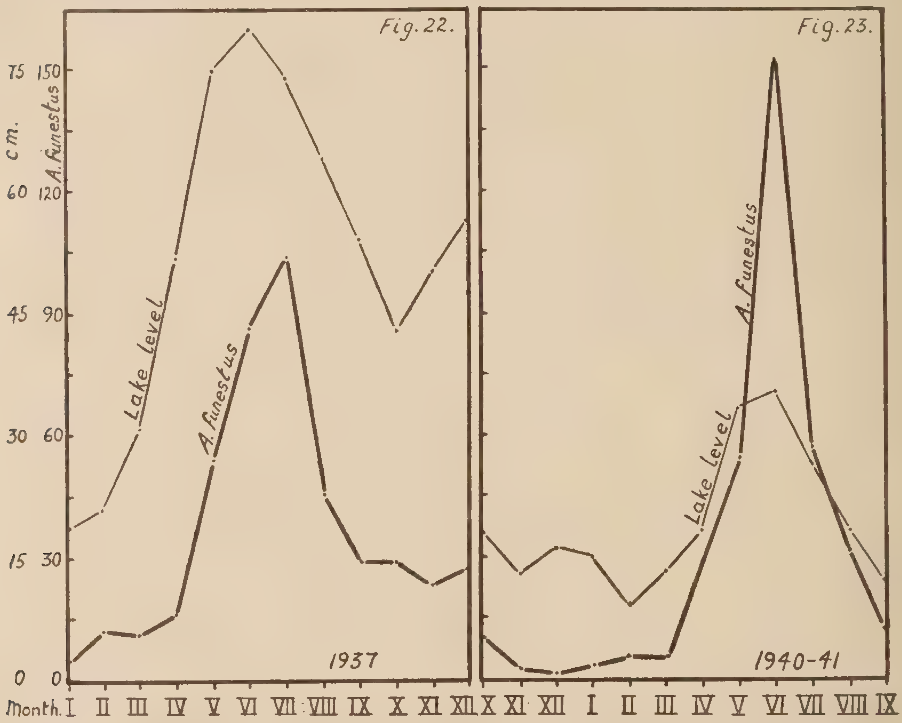
Fig. 21.—Scatter diagram showing correlation between monthly totals of *A. gambiae* males and females in day catches in control hut. The scale is doubly logarithmic for the sake of compactness.

(*b*) *Anopheles funestus.*

Previous work at Kisumu by Garnham (1929) has shown that periods of *A. funestus* increase are not associated with rainfall. In the year under discussion, 1940–41, an increase did actually occur during the long rains. During the preceding short rains, however, no increase had been apparent, and the long rains increase was maintained for a considerable time after dry weather had set in. Taking monthly figures, it was found that correlation between the incidence of this species and rainfall was not significant—r was only +0·04, while twice the standard error was 0·6. Obviously, local rainfall could not account for the seasonal incidence of *A. funestus*.

It has already been mentioned that the level of Victoria Nyanza shows an annual rise, due to the collective rainfall of a large part of East Africa, and independent of local rainfall. It was thought that this single rise in the lake level might be associated with the single annual increase of *A. funestus* which is normal at Kisumu and which usually occurs at some time during the period April–July. The mean lake level, measured in cm. above the datum line, was worked out, and was found to be closely correlated with the prevalence of *A. funestus* (r=+0·87 and twice the standard error =0·6). The results are shown in Table XXXVIII and fig. 23. In his paper of 1938, Garnham publishes a graph showing the monthly prevalence of *A. funestus* females in huts at Kisumu for the year 1937. With the object of confirming the 1940–41 findings, the lake level figures for 1937 were consulted, and it was found that once again correlation was very close, r being +0·88 and twice the standard error 0·6.

Garnham's figures (Table XXXVIII & fig. 22) as quoted here, should be regarded as approximate, as it has been necessary to standardise them, in order to place them on a comparable basis with the 1940–41 records. In comparing the graphs (figs. 22, 23) it should be noted that while the 1941 peak is better marked than the 1937 peak, it is of much shorter duration. Over the whole 12 months, the 1937 figures are much higher than the 1940–41 records.



Figs. 22–23: Mean catches of *A. funestus* females and mean lake level (cm. above datum line); (22) P. C. C. Garnham's figures, 1937; (23) author's figures, 1940–41.

TABLE XXXVIII.

Mean Catches of A. funestus *Females and Mean Lake Level (cm. above datum) at Kisumu.*

	Garnham 1937		Haddow 1940–41	
	Mean *A. funestus*	Mean lake level	Mean *A. funestus*	Mean lake level
October	—	—	10	18
November	—	—	2	13
December	—	—	1	16
January	5	19	3	15
February	12	21	5	9
March	11	31	5	13
April	16	52	7	18
May	54	75	54	33
June	86	80	152	35
July	104	74	56	26
August	45	64	31	18
September	29	54	12	12
October	29	43	—	—
November ...	23	50	—	—
December	26	56	—	—

It is obvious that the two sets of figures show similar trends. The comparison is made more interesting by the fact that while all the 1940–41 catches were made close to the lake shore, the 1937 catches cover a much wider area, including Kisumu township. The graphs, incidentally, show how much the lake level may fluctuate from one year to another.

The underlying mechanism is undoubtedly the increase in the swamp areas on the landward side of the papyrus belt, caused by the rise of the lake. Apart from this, the numerous irrigation furrows in native vegetable gardens are completely filled only when the lake rises. At other seasons they are dammed to hold back run-off water from local rainfall, which would otherwise drain to the lake. During the greater part of the year they are completely empty. It seems likely that, as in the case of rainfall and *A. gambiae*, there is some threshold lake level which being passed permits an increase of *A. funestus*.

It is interesting to note that since work in the special huts ceased in September 1941, abnormally heavy rainfall has occurred over a wide area. The rainfall at Kisumu for November and December 1941 is probably the highest on record for these months. The result has been a pronounced rise in the lake level. Mr. Harper's figures show that *A. funestus* has begun a distinct increase, quite abnormal for this season at Kisumu.

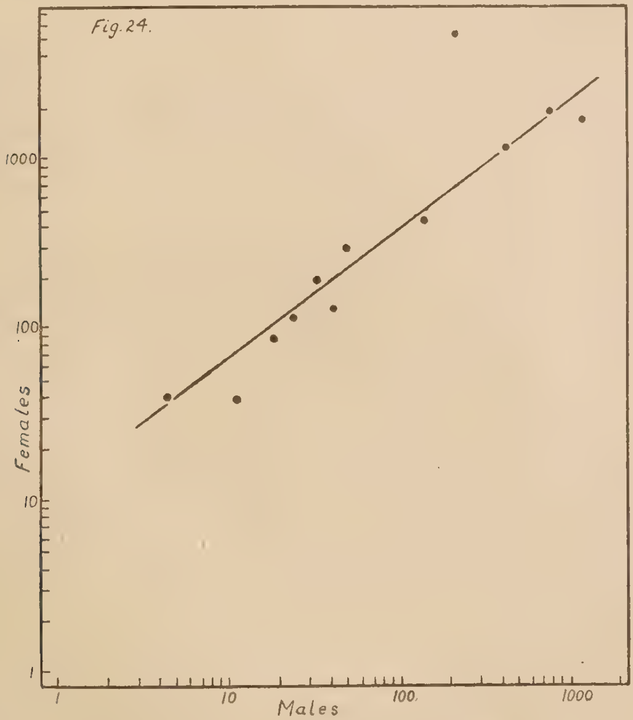


Fig. 24.—Scatter diagram showing correlation between monthly totals of *A. funestus* males and females in day catches in control hut. The scale is doubly logarithmic.

The seasonal incidence of males in hut catches was found to run parallel with that of females. The correlation between monthly totals for males and females in the control hut was very high (r=+0·98 and twice the standard error= 0·6). This is similar to the results obtained for *A. gambiae*, but in this case correlation is even more pronounced (fig. 24). Once again the figures confirm Lamborn's (1925) work in Nyasaland. It is again stressed that in the case of *A. gambiae* and *A. funestus* males are much more abundant in huts by day than by night and that therefore day catches form the best method of estimating the prevalence of these species.

(*c*) *Anopheles coustani.*

All specimens taken belonged to the var. *ziemanni*, Grünb. Evans (1938) has summarised the breeding-places of this variety at Kisumu and mentions swampy areas with tall standing vegetation near the papyrus zone and grass-grown drains. The peak incidence in 1941 occurred in May and June, during and after the long rains. At this season breeding-places of the types described by Evans were plentiful. *A. coustani* did not appear to increase during the short rains of November 1940. A possible explanation lies in the fact that at the beginning of the short rains vegetation was very scanty. By the time that tall reeds and grasses had grown the remaining areas of suitable water were very limited.

As this species is not very abundant in human habitations by night and is extremely scarce by day, it is felt that a year's night catches in a tent or cowshed would be necessary for a proper understanding of its seasonal incidence.

(*d*) *Anopheles pharoensis.*

This species breeds in similar situations to *A. coustani* but probably to a much greater extent in the papyrus swamps which, of course, exist all year round. The period of highest incidence lasted from May till September 1941. It thus seems that this species, like *A. funestus*, may be dependent on the annual rise of the lake level. Once again it is felt that a year's catches in a cowshed would be necessary for a complete understanding of the seasonal incidence.

(*e*) *Taeniorhynchus africanus* and *T. uniformis.*

These species are very abundant at Kisumu. They attained their maximum incidence in hut catches in September and October. It is difficult to account for this seasonal peak, as the *Pistia* beds, which form the principal breeding-grounds, are present all the year round. The *Pistia* beds in irrigation furrows are, indeed, liable to dry up at some seasons, but the largest beds grow outside the papyrus zone, in the lake itself.

(*f*) *Culex antennatus.*

This species reached its peak in hut catches during the period August–October. This is rather puzzling, as *C. antennatus* is a breeder in stagnant water in swamps, pools, drains, etc. At the season of maximum incidence the whole country was very dry and such breeding-places were scarce. As in the case of *A. coustani* and *A. pharoensis*, catches in cowsheds would probably give much fuller information.

Parasites of Mosquitos.

(*a*) *Mites.*

The small red mites which occur on mosquitos were usually commonest on *A. coustani*. Almost every specimen of *A. coustani* taken bore at least one mite. In December 1940, during the moderate *A. gambiae* increase, they became very prevalent on females of this species, particularly on newly emerged females. Infestations of 20–30 mites per mosquito were noted, and in these cases there was often gross distortion of the abdomen. It seems quite likely that heavy infestations of this type may cause the death of the mosquito in nature.

(*b*) *Coelomomyces africanus*, Walker.

The occurrence of this fungous parasite in Sierra Leone has been discussed by Walker (1938). Gibbins (1932) describes what was probably the same species from Uganda material. So far as is known, the present records are the first from Kenya.

Both Walker and Gibbins found the parasite more frequently in *A. gambiae* than in *A. funestus*. In the present instance the reverse was the case. About 30 natural infections of adult female *A. funestus* were recorded but only one infected *A. gambiae* female was found. No infected males of either species were taken.

In every case the ovary was primarily affected. In early stages, small numbers of sporangia were found grouped on the surface of the eggs. In later stages, the ovary was completely disorganised and semi-fluid. It was occupied almost completely by masses of sporangia. At this stage sporangia were sometimes found in other parts of the body. Mycelium was never prominent and was found in the ovary only. Except in very early cases infected mosquitos were easily recognised, without dissection, by the yellow colour of the abdomen.

Larvae bred from the egg were repeatedly fed on infected ovary by Dr. Garnham, but no infections resulted. Naturally infected larvae were taken in the papyrus swamp. Like the adults, they were recognisable by their yellow colour. Some of these larvae appeared to be almost completely filled with sporangia.

Attempts to Mark Individual Mosquitos.

(*a*) *Results of Staining Larvae.*

As the results of spraying adult mosquitos with dyes have nowhere proved consistently satisfactory, an attempt was made by Dr. Garnham and the writer to mark adults by staining the larvae.

Weathersbee & Hasell (1938) in tests of 16 dyes came to the conclusion that Giemsa was the best stain for such work. Professor R. M. Gordon and Dr. D. S. Bertram have carried out extensive tests with over 20 dyes at Liverpool, but have not been able to confirm this finding (private communication).

In the present case, five stains were tried, Gentian Violet, Methyl Green, Polychrome Methylene Blue, Congo Red and Giemsa. The results were completely unsatisfactory for practical purposes. In all cases the dye, sometimes changed in colour, could be recovered from the stomach. Unfortunately, this applied to the first day of adult life only. Dissections frequently revealed brilliantly coloured granules in the pericardial cells and at first these were sometimes mistaken for stain. The final conclusion was that results obtained by the study of such granules are absolutely unreliable. Wigglesworth (1939) states that these cells may normally contain yellow, brown, red or green pigment. As an example of how easily fallacies may arise from the use of such criteria, the experiments on methylene blue may be mentioned. Stained larvae were released near the control hut and on subsequent days adults taken in the hut were dissected. Some of these showed granules of a very bright blue in the pericardial cells. The colour was very like that of methylene blue. As the numbers of apparently stained adults seemed unduly large, mosquitos from other areas were examined, and some of these were found to contain granules of the same colour. Again, in the case of Congo red it was thought that success had been attained, the stain being apparently recoverable from the head. This again was a fallacy, the colour being due to the eye-pigment.

(*b*) *Attempts to render the Blood-meal identifiable.*

After the failure of the staining experiments described above, it was thought that mosquitos might be recognised by an examination of the stomach contents if the human bait had previously received intravenous injections of some recognisable substance.

The first trials were carried out with trypan blue. A native was given a series of 12 injections. At the end of the series his serum was persistently bright blue, the colour being sufficiently pronounced to be recognisable in the eyes, tongue and nails. Mosquitos were fed on this subject but dissection failed to reveal any blue coloration in the blood-meal, stomach or other organs.

Another native received 6 injections of T.A.B. At the end of the series his titre for paratyphoid B had risen to 1 in 2,500. Mosquitos, including large *Taeniorhynchus* females, were fed on this subject and were immediately dissected. The stomach contents were then put up for the Widal reaction, but no agglutinations were obtained. Dr. Garnham intends to proceed with further work on this line.

Summary.

1. Work on the mosquitos frequenting native huts was carried out at Kisumu, Nyanza Province, Kenya, during 1940–41.

2. During preliminary night and day catches in native huts the catching methods were standardised. Subsequently four identical huts were built side by side for comparative work. They were designed specially for easy catching and had hessian ceilings. Apart from catches made for special purposes, 6 day catches and 1 night catch were made every week in one of the huts for an entire year. This hut was regarded as a control. Records of climate were kept in this control hut for a year, the readings being compared with readings taken in a Stevenson screen outside.

3. It was found that the temperature range in the hut was only about half that in the screen—in other words, a native hut is a very well insulated structure. In hot, dry weather there were considerable differences between indoor and outdoor temperatures but in cool wet weather the differences were very small. Thermograph records showed that the form of the daily temperature curve in wet weather was quite different from that in dry weather. Temperature in the hut very rarely fell below the level at which development of the malaria parasite in the mosquito is arrested. In the screen it very frequently did so in the hours before dawn.

4. Hygrograph records of relative humidity in the hut and screen showed much the same characteristics as the temperature readings. Again the range in the hut was much smaller than that in the screen and differences between indoor and screen humidities were great in dry weather and small in wet weather. The form of the daily curve in dry weather differed markedly from the wet weather curve. Saturation deficit at night was always greater in the hut than outside.

5. At night, the climate of a hut containing 10 natives was compared with that of the control hut, containing 1 native. It was found that the crowded hut was slightly warmer than the other and that its relative humidity was somewhat lower than that of the control hut.

6. High wind at night was unusual. When it occurred the entry of mosquitos to huts was stopped for the time being.

7. A list of all species encountered is given, with locality records and sites of capture.

8. From the results of night catches the entry curves of various species were worked out. It was found that in the case of *A. gambiae* females there is a high population of resting mosquitos at 7 p.m., a period of low entry from 8 to 10 p.m., a period of high entry from 11 p.m. to 5 a.m., and a sharp entry peak at 6 a.m., due to the arrival of females seeking shelter for the day. The same remarks apply to *A. funestus* females, but the time distribution of the entry periods is different, namely :—7 p.m., a high population of resting mosquitos ; 8 p.m.–2 a.m., a long period of low entry ; 3–5 a.m., a short period of high entry ; 6 a.m., a large entry of females seeking shelter. In the case of both species, most of the females taken were

fed, and there is close correlation between the curves for fed and total females. It is thought that females remain in the hut after feeding. Mature females with Group V ovaries enter mainly at dawn. Males of both species are scarce during the night but enter in large numbers at 6 a.m. to rest during the day. *A. coustani* and *A. pharoensis* are scarce in the evening and at dawn. *A. coustani* shows a well defined entry peak from 11 p.m. till midnight and *A. pharoensis* from midnight till 2 a.m. *T. africanus* and *T. uniformis* act rather similarly. *T. uniformis* shows a very distinct entry peak at 9 p.m. and *T. africanus* from 9 to 11 p.m. There is close correlation in this case between *unfed* and total females. It is thought that these species leave the hut soon after biting and that their biting activity is at a maximum between 9 and 11 p.m. Thus the entry curves of the important species show a succession of entry peaks through the night—*T. uniformis*, 9 p.m. ; *T. africanus*, 9 11 p.m. ; *A. coustani*, 11–12 p.m. ; *A. pharoensis*, 12 p.m.–2 a.m. ; *A. gambiae*, 11 p.m.–6 a.m. ; *A. funestus*, 3–6 a.m.

9. Night catches, comparing dark and dimly lighted tents, showed that *A. coustani* entered tents in large numbers and preferred the lighted tent, as did *T. africanus* and *T. uniformis*. *C. nebulosus* preferred the dark tent. Catches made in the open showed that *A. gambiae* and *A. funestus* prefer to bite in huts, *T. africanus* and *T. uniformis* in the open.

10. Comparison of night and day catches showed that the mosquitos taken may be divided into 4 groups :—

> 1. True house-haunting species, *A. gambiae* and *A. funestus*. Females are abundant both by night and by day, males by day only. These species enter both for food and for shelter. Day catches, which included both males and females, give the best estimate of prevalence.
>
> 2. Species which enter mainly to feed, *T. africanus* and *T. uniformis* ; perhaps *A. coustani* and *A. pharoensis*. Females are common by night but are never numerous by day. Males are always scarce. Night catches are essential for an understanding of this group.
>
> 3. Species which enter *human* habitations mainly for shelter, *C. antennatus*. Females are prevalent by day only.
>
> 4. Species which enter casually and are scarce both by night and by day.

11. Analysis of day catches showed that the great majority of *A. gambiae* and *A. funestus* females had Grade 1 wings. Sometimes the wings were still undamaged when the ovary was maturing for the second time. Ovary dissections of these species showed that the largest numbers belonged to Group I and that the percentage in this group became higher at times of increase. Most females of these species and of *T. africanus* and *T. uniformis* contained blood. Of the unfed *A. gambiae* and *A. funestus*, the great majority had Group I ovaries, *i.e.*, they were young females which had never yet fed.

12. Analysis of an *A. gambiae* increase (December 1940–January 1941) by ovary dissection of day catches showed that the whole increase was dependent on a constant supply of young females with Group I ovaries. As soon as this supply diminished the increase came to an end. It seems, therefore, that the life of the female was short at that season. The numbers of males and females taken were closely correlated throughout.

13. In day catches the great majority of Anophelines were taken on the ceiling. *Taeniorhynchus* spp. were commonest on the walls. Very few mosquitos were found on the floor. With regard to mosquitos taken on the walls, it was found that all species preferred the lower and darker half. Catches made on the outside of the walls consisted mainly of male Anophelines.

14. In comparative series of catches made to determine the best hour for day catching, no significant difference was found between catches made at all hours from 6 to 11 a.m.

15. Preliminary tests showed that there was probably a quantitative relationship between the numbers of human inhabitants of a hut and the numbers of mosquitos taken. This was confirmed by night and day catches made simultaneously in huts with 1, 5, 10 and 15 inhabitants respectively. It was found that there was a very close direct relationship between the size of the human population and the numbers of females of biting species taken. Non-biting species did not discriminate between the huts.

16. Comparison was made between huts containing 5 washed and 5 unwashed natives respectively. All the important biting species preferred the hut with the unwashed natives.

17. In night catches, *A. gambiae* and *A. funestus* females preferred a hut containing dirty clothing only to a completely empty hut. Females of *T. africanus* and *T. uniformis* showed no such preference.

18. Catches in empty huts showed a relative but not an absolute increase in Anopheline males.

19. It was found that a hut subdivided by a hessian curtain could be used for preference experiments with varying human population.

20. In a comparison between a hut containing a native and one containing a calf, it was found that *A. gambiae* and *A. funestus* were more numerous in the hut with the native both by day and by night. *A. funestus* showed a more marked preference for the native than did *A. gambiae*. *A. coustani*, *A. pharoensis* and *C. antennatus* showed a distinct preference for the calf. In the hut with the native, Anophelines formed 94 per cent. of the total catch, but in the calf hut Culicines formed 95 per cent. of the total.

21. It is shown that at Kisumu the seasonal incidence of *A. gambiae* is dependent on local rainfall. The relationship is qualitative rather than quantitative. A threshold figure of 5 inches of rain per month is necessary before an increase can take place. When an increase does occur, the population in the first month of the increase is proportional not to the amount of rain which has fallen but to the lower initial population of the preceding month. If the increase is maintained for several months, the growth of the population takes place in geometrical ratio.

22. At Kisumu the seasonal incidence of *A. funestus* is not connected with local rainfall. Increases take place when the level of Victoria Nyanza rises. The rise in lake level is dependent on the rainfall of a large part of East Africa and is independent of local rainfall.

23. The seasonal incidence of other species is briefly discussed.

24. The parasites noted from mosquitos were mites, which were most prevalent on *A. coustani* and *A. gambiae*, and *Coelomomyces africanus* which was commonest in *A. funestus*. *Coelomomyces* is a fungous parasite which causes destruction of the ovaries. It is now recorded from Kenya for the first time. Unsuccessful attempts were made to infect larvae with this fungus, but naturally infected larvae were found.

25. Unsuccessful attempts were made to render adult mosquitos individually recognisable by staining the larvae with various dyes. Attempts to make the blood-meal recognisable by injecting identifiable substances into the blood-stream of the human bait were also failures.

Acknowledgments.

I have pleasure in thanking Professor P. A. Buxton, London School of Hygiene and Tropical Medicine, who has supervised the work, for the constant interest he has taken and for a great deal of useful advice and criticism. I am indebted to Dr. A. R. Paterson, Director of Medical Services, Kenya, who has given me every facility and encouragement. I wish to thank specially Mr. C. B. Symes, Government Entomologist, Kenya, Dr. P. C. C. Garnham, M.O.H., Kisumu, and Mr. J. O. Harper, Health Department, Kisumu, who have helped me in every possibly way and whose wide knowledge of East African mosquitos has constantly been at my disposal. I wish also to thank the British East African Meteorological Service for access to their records, and the Kenya and Uganda Railways and Harbours for travel facilities and for permission to use their records of the lake level.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st January and 31st March, 1942 :—

Mr. A. L. Abel :—18 Parasitic Hymenoptera ; from England.

Dr. H. F. Barnes, Rothamsted Experiment Station :—1 Cynipid ; from England.

Mr. G. E. Bodkin :—35 Parasitic Hymenoptera and 17 Lepidoptera ; from Mauritius and Madagascar.

Dr. G. Bondar :—4 Coleoptera and 200 early stages ; from Brazil.

Mr. J. M. B. Brown :—2 Coleoptera, 21 Parasitic Hymenoptera, and 9 cocoons ; from England.

Chief Entomologist, Pretoria :—16 Parasitic Hymenoptera ; from South Africa.

Mr. J. L. Froggatt, Government Entomologist :—34 Diptera, 88 Coleoptera, 13 Parasitic Hymenoptera, 35 other Hymenoptera, 48 Lepidoptera, and 13 Rhynchota ; from New Guinea.

Government Entomologist, Kampala :—593 Coleoptera, 8 Lepidoptera, 259 Rhynchota, and 6 Orthoptera ; from Uganda.

Mr. W. D. Hincks :—143 Coleoptera ; from various localities.

Mr. G. H. E. Hopkins, Medical Entomologist :—39 *Glossina* ; from Uganda.

Mr. J. R. Erichsen Jones :—9 Coleopterous larvae ; from Wales.

Mr. R. A. Lever, Government Entomolgoist :—3 Diptera, 40 Coleoptera, 47 Parasitic Hymenoptera, 11 Formicidae, 10 Lepidoptera, 10 Thysanoptera, 1 species of Coccidae, 1 species of Aphidae, 6 other Rhynchota, 8 Psocidae, 3 Orthoptera, 3 Ticks, 14 Crustacea, and 4 Slugs ; from Fiji.

Dr. O. W. Richards :—2 Coleopterous larvae ; from England.

Dr. W. E. Ripper :—6 Parasitic Hymenoptera ; from England.

IMPERIAL INSTITUTE OF ENTOMOLOGY.

Sir Guy Marshall, K.C.M.G., F.R.S., D.Sc.
and
Dr. Sheffield A. Neave, C.M.G., O.B.E.

Sir Guy Marshall has been Director of the Imperial Institute (formerly Bureau) of Entomology, since it was founded in 1913. He is known personally or by repute to most entomologists in the world. A numerous and widely scattered circle of friends will regret his retirement on 31st July as deeply as do the Executive Council and the Staff of the Institute. He takes with him all their best wishes. His connections with the Institute are not, however, being severed entirely. For the time being he will continue his work on the identification of certain groups of insects and, at the invitation of the Secretary of State for the Colonies, his supervision of the work of the Anti-Locust Research Centre.

He is being succeeded as Director by Dr. S. A. Neave, C.M.G., O.B.E., who has been Assistant Director since 1914 and has been for many years in charge of the *Review of Applied Entomology*. Latterly he has completed and issued the *Nomenclator Zoologicus*—an indispensable book of reference. Many know him personally ; many more know the publications for which he has been responsible.

Sir Guy was appointed Scientific Secretary to the Entomological Research Committee (Tropical Africa) on 1st July, 1909. At the same time Dr. S. A. Neave was appointed one of the two entomologists to work in Tropical Africa. " If we are to make our Central African colonies habitable and profitable and healthy, increased attention should be paid to the insect fauna, whether inimical or beneficial, but in the first instance to the former," expressed the purpose of the new Committee. The receipt of specimens sent in by the collectors, their identification, report back on them to the collectors, and the issue of a Bulletin that it was hoped might be published, were the chief duties of the Secretary. In fact, the first part of the *Bulletin of Entomological Research* was published in April 1910. It is now in its thirty-third volume, and Sir Guy Marshall has been its Editor throughout this long period. Applied Entomology was thus the objective ; " the judicious encouragement and stimulation of the field workers by correspondence " and the dissemination of information were to be the means, not detailed direction and control of the work of the entomologists in the field.

This small organisation was soon extended. With the active support of Canada, it became in 1913 a truly inter-imperial service maintained by and serving all countries in the British Commonwealth. The *Review of Applied Entomology*, surveying regularly all current literature on Economic Entomology, was started. Sir Guy has been in charge throughout, and throughout the methods have remained the same—help, stimulation and dissemination of knowledge and information to the man in the field and to entomological departments ; never control or dictation. The service has proved its worth ; the bureaux which have come later follow those same principles, proved and tested by the Institute. The service Sir Guy built up has extended far beyond anything he imagined in 1909.

S. LALL,
Chairman,
Executive Council of the Imperial
Agricultural Bureaux.

21st July, 1942.

A METHOD OF SAMPLING THRIPS POPULATIONS.

By Richard H. Le Pelley.
Department of Agriculture, Kenya. E.M

For a study of population trends of *Diarthrothrips coffeae*, Williams, on coffee in Kenya, and to assess the value of sprays for its control, a method of sampling the population was required. This insect feeds on the leaves, green shoots, and berries ; but by far the greater part of the population lives on the leaves. Attempts to count the insects on the leaves in the field, by naked eye or with a hand lens, proved difficult and inaccurate. Two other methods were tried, those of E. A. McGregor (Pan-Pacif. Ent., **3**, 1926, p. 29) and J. W. Evans (Bull. Ent. Res., **24**, 1933, p. 349). The former proved unsatisfactory for several reasons such as the failure of the insects to forsake the leaves, the collection of debris on the grease tending to conceal insects, and the difficulty of counting the insects in the grease. The method of Evans was designed originally for obtaining the thrips from blossoms, but an examination of the method was made with the coffee thrips. Fairly consistent results were obtained with it, but the figures were low and it was clear that the sampling was not complete. It was found that a number of insects remained among the leaves and failed to reach the paper at the bottom of the cylinder. There are other disadvantages ; for example a large number of the cylinders are necessary to carry out a single spraying experiment, they are usually difficult to come by and the work of counting has to be done in the field, requiring a rather elaborate provision of tables and microscopes. Further it was found that even a light breeze was apt to cause loss of thrips during the counting.

The method finally developed avoided all these disadvantages, and it should prove of value in counting similar insects. Glass sixteen-ounce bottles with screw cap and wide mouth are filled with 70 per cent. alcohol. Coffee leaves are picked and dipped into the alcohol, drained off into the bottle and then thrown away. The alcohol is finally filtered, and the thrips present on the filter paper are counted under a low-power binocular dissecting microscope. The filter paper is ruled with lines a little less than 1 cm. apart, the space between the lines being comfortably retained in the field of the microscope. Each space between lines is numbered, preferably at both ends, to assist in covering the whole field expeditiously. *Diarthrothrips coffeae* is a light-coloured insect, rather difficult to see on white filter paper ; it was thought that it might be possible to dye the filter paper, but none of the dyes used was successful, and I owe acknowledgments to Mr. V. A. Beckley, Senior Agricultural Chemist and to Mr. W. Politzer, also of the Chemical Section of the Kenya Department of Agriculture, for suggesting the following ingenious method, which is to make a blue print of the filter paper, using a negative with the lines and numbers drawn in indian ink on tracing cloth. The solution with which the filter paper is saturated is an ordinary blue print formula made up as follows :—

A.	Ferric ammonia citrate (green)	250 gm.
	Water	1 litre
B.	Potassium ferri cyanide	90 gm.
	Water	1 litre

These are mixed in equal parts, kept in the dark, filtered just before use, and applied with a brush or sponge. The paper is printed to a dark colour, and the thrips stand out remarkably clearly on the dark blue background. I used Whatman No. 1 filter paper of 15 cm. diameter and a paper of this quality can be used over and over again, thus avoiding frequent blue printing ; the alcohol can also be used many times, and though it gradually darkens owing to dissolved chlorophyll, this is of no significance. The method has the following advantages :—

1. As the thrips immediately float off in the alcohol, very nearly the total population is obtained.

2. Any number of leaves can be used for one sample (in practice I used from 20 to 200).

3. The sampling requires little apparatus in the field, and the final examination can be made in the laboratory.

4. The bottles may be kept as long as desired before examination as the thrips remain in good preservation.

5. Different species of thrips, and other small insects on the leaves (other than those with mouth-parts inserted in the tissue), can be counted. In some samples from coffee leaves, six species of thrips were obtained.

6. The method can be used for general collecting, as well as for sampling, and the insects are in satisfactory condition for slide mounting.

The following results indicate the superiority of this method over the Evans method, for the sampling of this particular leaf-inhabiting thrips. Twenty leaves were sampled, four from each of five trees, on each of nine plots, by both methods.

	Number of Thrips obtained from twenty Leaves	
	Evans method	Alcohol method
Plot 1	35	120
2	100	218
3	52	152
4	142	209
5	107	231
6	125	247
7	26	91
8	45	156
9	74	182

No detailed statistical study has been carried out to determine the number of leaves necessary to give an adequate sample, but the following results show the variability which occurred in repeating the sampling eight times on the same block of 16 trees, four leaves being taken from each tree :—

438, 554, 442, 454, 401, 375, 435, 349. Mean 431. Standard error ±22.

The leaves used for the fifth repetition (which produced 401 thrips) were thoroughly washed immediately afterwards and seven thrips were obtained, a loss in the first dipping of less than 2 per cent. This could be cut down by expending a little more time in dipping and draining the leaves.

A further similar trial with 10 repetitions on a different block, again using 64 leaves, four from each of 16 trees, gave the following figures :—

230, 200, 172, 170, 130, 148, 201, 161, 152, 158. Mean 172. Standard error ±9.

THE DISTRIBUTION OF THE EUROPEAN SPRUCE SAWFLY, *DIPRION POLYTOMUM* (HTG.) IN THE SCANDINAVIAN AND EASTERN BALTIC COUNTRIES.

By Wendell F. Sellers, B.Sc.*

Senior Entomologist, Parasite Service, Imperial Institute of Entomology.

(Plate IV.)

Introduction.

Since 1930, when a severe sawfly outbreak was first noticed over a large area of spruce woodland in the centre of the Gaspé Peninsula in eastern Quebec, Canada, the insect concerned has become one of the outstanding forest-insect pests in north-eastern North America. This insect, the European spruce sawfly, *Diprion polytomum*, Htg., is known to occur in Canada in the provinces of Nova Scotia, New Brunswick, Quebec, and Ontario, the area of severe damage comprising portions of Quebec and New Brunswick. Outbreaks have occurred in several regions in the United States, and it is a menace to the spruce forests in the New England States, New York and New Jersey.

The known native habitat of the European spruce sawfly is Europe. Although references in literature indicate a wide distribution extending from Finland southward wherever spruce occurs, it is a comparatively rare insect. One female† was found on the peninsula of Kamchatka in north-eastern Asia.

Since 1932 the Division of Entomology, formerly the Entomological Branch, of the Canadian Department of Agriculture, and the Farnham House Laboratory of the Imperial Institute of Entomology, England, have been collecting and studying natural enemies of the European spruce sawfly and other sawflies in Europe, with the object of sending them to Canada for use in a campaign against the sawfly.

The field investigations of the Farnham House Laboratory on the European spruce sawfly have been confined principally to Czechoslovakia and the contiguous portions of Germany. Prior to 1938, all collections of *Diprion polytomum* were made in Czechoslovakia, as an extensive search in Europe showed this to be the only country where appreciable collections were possible. During the first three years the collections were small, so considerable attention was given to obtaining parasites from other species of sawflies, principally *Neodiprion sertifer*, Geoff. Millions of cocoons of this latter sawfly have been obtained in widely scattered areas from Sweden to Yugoslavia for shipment to Canada. Recently, however, emphasis was again placed on the collection of *D. polytomum* so that its more specific natural enemies might be obtained. Because of the low populations encountered, the available areas could not provide a very great increase in numbers, even if worked more intensively. The possibility always existed that climatic or other factors might be greatly restricting the populations in the known collecting places. During the spring of 1938, the precarious political situation in Czechoslovakia threatened the availability of all that section as a collecting area.

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* When this survey was made, the author was connected with the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, Division of Foreign Parasite Introduction.

This paper was approved for outside publication by the U.S.D.A., Bureau of Entomology and Plant Quarantine.

† Collected by Dr. R. Malaise of the Naturhistoriska Riksmuseet, Stockholm, Sweden.

As the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture and the Canadian Division of Entomology were interested in obtaining natural enemies in Europe, it seemed advisable, in order to obtain the most efficient results, to attack the problem as a cooperative project. It was agreed that the Farnham House Laboratory should continue the exploitation of the Czechoslovakian areas, and that the Division of Foreign Parasite Introduction of the Bureau of Entomology and Plant Quarantine would attempt to locate new areas in sections of Europe not previously covered by the Farnham House Laboratory. Under this arrangement the writer made a survey of the Scandinavian and eastern Baltic countries during the spring and summer of 1938 to extend the knowledge of the distribution of the sawfly ; to discover, if possible, better or equally good collecting grounds where new species of parasites might be found ; and to obtain additional information regarding the better known species of parasites.

Dr. Gernot Bergold, of Vienna, Ostmark, Germany, and Mr. O. Conde, of Riga, Latvia, acted in the capacity of field assistants. Dr. Bergold assisted in obtaining the desired information in the Scandinavian countries, and Mr. Conde in the eastern Baltic countries.

During the course of the survey the Canadian Division of Entomology had been following our progress in studying the distribution of the European spruce sawfly in Scandinavia. Late in July they requested the Farnham House Laboratory to ship them some cocoons. As the Farnham House Laboratory was not in a position to supply an entomologist on such short notice, arrangements were made for Dr. Bergold to make the desired collections. These were made at Ounistunturi, in Sweden ; and at Salla, Kuusamo, and Pallastunturi, in Finland.

Bioclimatic Considerations.

The principal food-plant of *Diprion polytomum* in Europe is the Norway spruce, *Picea excelsa*, Link, a boreal tree which, north of the Arctic Circle, is confined principally to the continental watershed. In Finland some spruce was found growing on the Arctic watershed. The northernmost record of the occurrence of *D. polytomum* is in Ivalo-Inari, Finland, latitude 68° 45′, on the Arctic watershed. This is about as far north as it is possible to find spruce at all common, for although it occurs farther to the north, it is very scarce and was not encountered during this survey.

With due respect to microclimatic variations, the survey demonstrated that although the European spruce sawfly may be found wherever spruce occurs, it will be more plentiful in areas which provide a maximum of heat from the sun and at the same time plenty of moisture and shelter. This combination of conditions, which seems to provide an optimum habitat, occurs more frequently near the upper limits of spruce growth in the northern Arctic areas or in the high mountain areas of central Europe. The bioclimatic conditions are alpine in character and essentially the same in both regions. Inasmuch as these conditions are not influenced so greatly by the range of altitude in the North to obtain the same record isophanal position as in the mountainous areas of central Europe, the area favourable for the development of the sawfly is greater. In the high-mountain localities of central and south-eastern Europe and in northern Sweden and Finland, the period for growth is so short that the development is restricted to one complete generation annually. The population of the sawfly in the mountains will probably be more sporadic, and the insect will be more plentiful only where conditions allow for the creation of " heat pockets," whereas the midnight sun furnishes a steadier and more uniform accumulation of heat which affects the whole region. The adults, like most sawflies, are sun-loving insects, and will invariably congregate in sunny areas, especially where sheltered from winds, and where the humid conditions greatly contribute to the quality of the needles and the chances for survival of the larvae.

From the standpoint of collecting full-grown larvae (Plate IV, figs. 1, 2, 3), the European spruce sawfly is not so abundant in the two-generation as in the one-generation areas. This should not preclude the possibility of the sawfly being as numerous under a combination of factors approaching those of the one-generation areas. All the favourable factors, however, are rarely attained in the two-generation areas.

Distribution and Habitat.

The Scandinavian countries surveyed were Denmark, Norway, Sweden, and Finland. The eastern Baltic countries surveyed were Estonia, Latvia and Lithuania. Inquiry by correspondence concerning the possibility of collecting appreciable

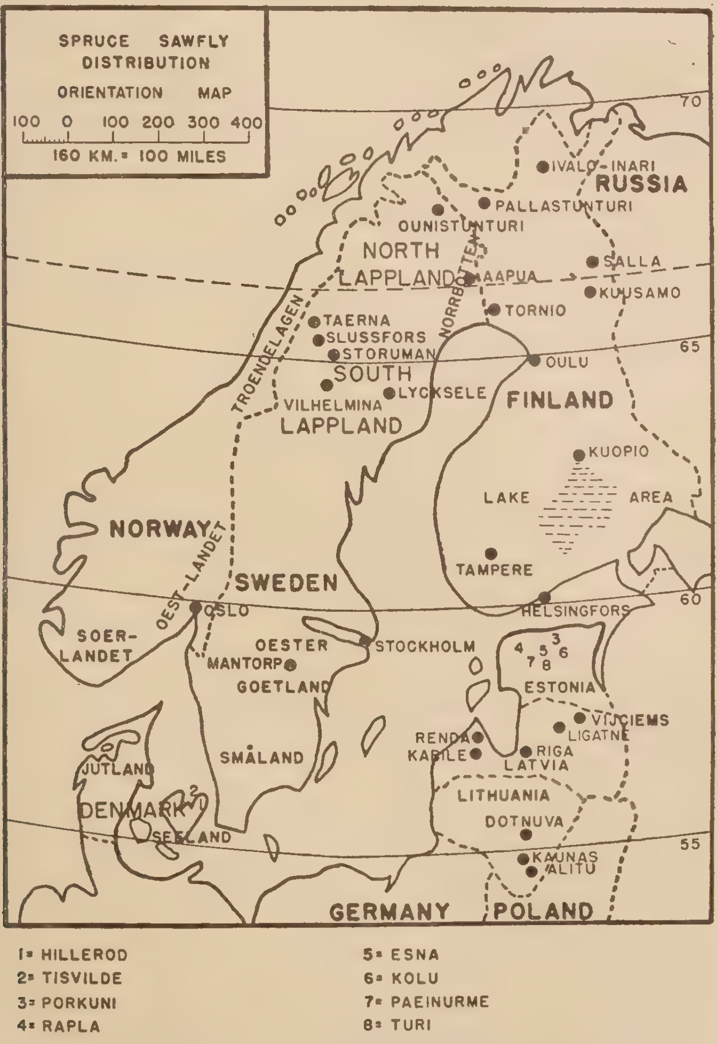

Fig. 1. Outline map of area surveyed for *Diprion polytomum*, Htg.

numbers of the sawfly in the Scandinavian countries had been without positive assurance, and when the survey was undertaken, the prospects were not at all encouraging.

Each country will be discussed separately. The approximate locations of the regions where collections were made are indicated on the rough outline map (fig. 1).

DENMARK.—The forest area of Denmark comprises 3,500 square kilometres.* Of these 780 are of pure spruce, *Picea excelsa*, and an additional 430 are spruce mixed with *Pinus montana*, Mill.

Borries (1895–96) stated that *Lophyrus hercyniae* (*D. polytomum*) had been known in Denmark since 1838, that it was distributed throughout the country, and that he had found the larvae wherever he had looked for them. According to the published records and the specimens available at the Royal Veterinary and Agricultural College and at the Zoological Museum in Copenhagen, adults and larvae had been taken from 18 localities. Borries stated that the male of this species [at the time he wrote] was unknown, but among 28 specimens examined at the museum there was one male which had been taken in south-western Jutland in 1932. Wuestnei's European collection contained 8 males and 12 females, four of the males having been taken at Chodan, Germany, just south of the Danish border.

The Noedebo Forest in Hilleröd, north-eastern Seeland, was visited on 17th, 18th and 20th June. Larvae were collected from five different parts of the forest. The Tisvilde district, Fredericksvaerk, north-eastern Seeland, was visited on 21st June, and larvae were collected from two of the four places visited. *Diprion polytomum* had been taken previously from the Tisvilde district, but the Noedebo Forest is believed to be a new distribution record.

The *polytomum* larvae from the Noedebo Forest came from sheltered areas, usually with a southern exposure. One locality was a typical open swampy area possessing a very scattered mixture of spruce, pine, birch, and other trees. The other places were on the borders of dense spruce areas. Only 47 larvae, two fifth-instars and the others smaller, and one cocoon, were collected in two days, indicating that the insect could not be considered at all abundant.

The Tisvilde district contains a mixture of spruce and pine planted as a windbreak bordering on the ocean and very much exposed to strong winds. The forest floor was of sandy formation with enormous numbers of ant colonies scattered throughout the area. That this proved to be a poor collecting area was attributed to the lack of humidity caused by constant winds blowing over the sandy soil. The larvae were always scarce in dry areas, and it was practically impossible to find larvae in the immediate vicinity of an ant colony or on trees overrun with ants. Seven *polytomum* larvae, two of which were fifth-instars, were collected.

From both localities most of the larvae were third- or fourth-instars, and the last of the cocoons were formed a month later. An adult male issued on 10th July from a cocoon collected 18th June. There are two generations in Denmark, larvae being numerous in July and again in September.

NORWAY.—The total area of Norway is 323,793, or, after deducting water areas, 309,410, square kilometres. Of this, 77,442 square kilometres, or 25 per cent., are productive forest areas, 54,422 being in coniferous forest, of which 30,202 are spruce. The spruce areas represent 39 per cent. of the total forests. The largest spruce areas are in Oestlandet and Troendelagen. In Norway spruce forests do not occur north of the Arctic Circle.

So far as is known, the occurrence of *Diprion polytomum* in Norway has not been recorded in the literature. The collection at the Museum in Oslo, however, contained four specimens which had been identified as *Lophyrus hercyniae*. One of the specimens came from Nord Troendelag, one from Oslo, and the other two from localities near Oslo. Nord Troendelag is in the northern portion of the Troendelagen area located in the central part of Norway just above latitude 64°.

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* 2·59 square kilometres equal 1 square mile.

Nineteen larvae of *Diprion polytomum* were collected in the environs of Oslo at Frognersaeterens and Holmenkolen on 21st September. These larvae were fifth- and sixth-instars, and represented what appeared to be the last available specimens of the second generation. They were collected at an elevation of between 400 and 500 metres (1,300 to 1,600 feet) in open areas, with a southern exposure. Most of the larvae were collected on spruce growing on the banks of a small lake. This collection did not greatly extend the areas of known distribution, but it did indicate that this sawfly could be collected in Norway.

As Norway is both a mountainous and a northern country and the limits of spruce growth occur in many places, the northern spruce areas may possibly be found to excel Sweden and Finland as a desirable habitat of the European spruce sawfly. As the location of the desirable spruce areas is a matter of climate dependent somewhat on elevation, the best conditions will be found south of the Arctic Circle in contrast to north of the Arctic Circle in Sweden and Finland. The Troendelagen region is a one-generation area, whereas southern Oestlandet and Soerlandet (south-eastern Norway) represent a two-generation area.

SWEDEN.—The total area of Sweden is 410,545 square kilometres, with 231,812 square kilometres in productive forests, of which 56,209 are spruce and 66,136 mixed spruce and pine. The spruce represents nearly 40 per cent. of the total forest area. In Sweden spruce forests are found about 100 miles north of the Arctic Circle.

So far as is known, there is very little in the literature concerning the occurrence of *Diprion polytomum* in Sweden. Borries (1895–96) mentioned that the species was most numerous in Sweden and Denmark. In the Museum at Stockholm there were 10 females from eight provinces of Sweden extending from Småland in the south to South Lappland and Vaesterbotten in the north.

The collections made by the writer and his assistants in Sweden in 1938 are shown in Table I.

One larval collection was made on 24th June in southern Sweden at Mantorp in the province of Oestergoetland. The larvae were mostly fourth and fifth instars and were taken along a fire line and in large open areas on top of a slight elevation. One male and two females issued on 12th and 13th July. The spruce stands of southern Sweden are dense, and collecting of larvae is possible only along the edges. Two generations occur in southern Sweden.

In northern Sweden the pine woodlands occur in the dry areas and spruce in the wet areas. The roads are constructed through the dry pine areas, and towns are located along these roads. The spruce areas are inaccessible to a certain degree in the sparsely settled sections of the north. Spruce grows everywhere, but there are distinct areas of pure spruce. The European spruce sawfly is most abundant in the pure spruce areas and less abundant on spruce growing in mixture with pine on the drier areas.

In the province of Norrbotten collections were made at five localities, all of which were north of the Arctic Circle. Aapua is in a large pure spruce area, the lower end of which is cut by the Arctic Circle. Jarhois and Svanstein are on the eastern edge of this area.

In the province of North Lappland collections were made at Ounistunturi in the northernmost spruce area of Sweden. On 11th and 14th July the larvae were mostly first and second instars, indicating that they had hatched a few days earlier. This large pure spruce area, a hilly terrain reaching an elevation of 593 metres (1,945 feet) at the top of Mt. Ounistunturi, which is above the tree line, is situated a little south of latitude 68°, roughly 100 miles above the Arctic Circle. It is typical of the far north. The individual trees were from 30 to 60 feet high and were spaced from four to five yards apart. The branches were short as compared with the southern type of spruce. Owing to the open character of the stands, the branches extended all the way to the ground. Birch and low arctic flora grew between the spruces. On the northern side of the area single spruce trees grew here and there among and over-

TABLE I.

Collections of Diprion polytomum *made in Sweden in 1938.*

Locality*	Date	Number of larvae	Collecting place or period and remarks
Province Oestergoetland :—			
Mantorp	24 June	12	1 male reared
Province Norrbotten :—			
Kaalamaa	6 July	12	Swamp
Kengis	8 July	5	Roadside
Jarhois	12 July	6	Small swamp
Svanstein	12 July	14	Low area
Aapua	12 July	25	60 minutes
Province North Lappland :—			
Ounistunturi			
Km. 103·5 (road marker)	11 July	9	30 minutes
Km. 106		32	60 minutes
Km. 107–108	14 July	14	
Km. 106		65	90 minutes
Km. 103·5		35	50 minutes
Km. 102		16	10 minutes
Km. 100·5		6	
Km. 96–97		17	20 minutes
Ounistunturi	3–19 Aug.	27,122	17 days
		374	Of the red form
Province South Lappland :—			
Lycksele	19 July		
Ledaburg		4	
Skaraborg		3	
Graned		5	
Aspås		4	
Lycksele-Taerna			
Lycksele-Storuman	21 July		
Avalund		2	
Gunnarin		2	
Nysele		1	
Storuman-Slussfors	21 July		
Sandvik		13	45 minutes
Blaiken		6	30 minutes
Talltraesk		9	30 minutes
Gardsjoenas		2	2 places
Taerna	22 July		
Norvick		4	
Melansjo (3 places)		68	2 hours
Taerna		29	30 minutes
Sundsgården		6	1 female
Vilhelmina-Lycksele	23 July		
Granberget		4	2 places
Norrbaeck		1	

* The underscored localities and areas are located on the outline map (p. 151).

topping the birches. Larvae could be collected on all sides of the spruce trees. Adult sawflies spend considerable time in the sunshine during the heat of the day. In the north, during the season of the midnight sun, there is at times little difference in the temperature between day and night.

Typical larvae of *Diprion polytomum* are uniformly dark green with three characteristic milk-white, narrow, longitudinal dorsal stripes with an additional stripe on each side just above the spiracles. A relatively small number were of a reddish colour. These reddish larvae were of two types, one with a rose-red venter and the other (Plate IV, fig. 4) salmon red in colour throughout with a greenish tinge. The venter of the red, fifth-instar larva was a dirty yellow red tinged with green.

During the first half of August Dr. Bergold collected at Ounistunturi 27,122 typical and 374 red full-grown larvae, from which 15,553 and 305 cocoons, respectively, were obtained. The larval population where collections were made averaged about 20 per tree. The largest numbers of larvae found on any tree were 101 and 96. Collections of more than 1,000 larvae per man day were made at the beginning of the work at Ounistunturi.

After the middle of July some collections were made in the vicinity of Lycksele in the province of South Lappland about 135 miles south of the Arctic Circle. Beautiful and extensive spruce forests grow in this area. The stands are dense and some trees are 200 years old. The stands are progressively less dense as one goes north. The collecting of *polytomum* larvae was a discouraging proposition in a large area around Lycksele.

A collecting trip was made from Lycksele to the north-west to Taerna in the mountain areas near the Norwegian border, a distance of 200 kilometres. In this region the mountains rise above the tree line. The trip was through a long valley in which pine was the predominant tree species in the lower portions. Although spruce was abundant, only five larvae were collected between Lycksele and Storuman. As the valley became higher and spruce was more abundant, the collecting became progressively better. Thirty larvae, mostly third instars, were collected at five places between Storuman and Slussfors.

Taerna, at a latitude of 65° 30′, which is nearly the same latitude as the Troendelagen area in Norway, is on the extreme western limit of spruce in the mountains. Here the collecting was reasonably good and at times comparable with that in the Ounistunturi area. The infestation, instead of being as uniform as in the north, was definitely sporadic. It appears quite evident that this sawfly becomes more abundant in the mountain areas near the upper limits of spruce. Optimum conditions appear to be in wet mountain meadows, valleys with streams, and along lake shores where spruces are exposed to the sun. There were glaciers and much snow on the mountain tops, the melting of which contributed greatly to the humid conditions in parts of this area. Larvae were invariably more abundant on the northern side of a lake completely surrounded by hills, or where heat pockets were created for short periods by intense sunlight during the middle of the day while the surroundings remained humid.

The return to Lycksele was made via Vilhelmina. Although many stops were made, larvae were collected at only three places and only five larvae in all.

The collections made on this trip from Lycksele to Taerna and back indicated a correlation between humidity and the intensity of the population, *i.e.*, at lower altitudes it is drier, and even though there is sufficient heat, the habitat is not favourable for *Diprion polytomum*.

FINLAND.—The total area of Finland is 343,599 square kilometres. Over 201,000 square kilometres are devoted to productive forest land, of which 57,000 are in spruce. In Finland, on the Kemijoen (continental) watershed, spruce forests are found growing more than 150 miles north of the Arctic Circle. There are some scattered spruce on the Pohjoisen Jaeaemeren (Arctic) watershed about 180 to 200 miles north of the Arctic Circle.

Diprion polytomum has been recorded several times in Finnish literature. The collection at the museum in Helsingfors and the private collections of Doctors Hellén, Groenblom, Linquist, Kangas, and Forsius, and Abo University indicate that over 100 specimens have been taken from at least 38 localities all over Fennoskandia, but mostly in Finland. The Fennoskandia area includes Finland, the Kola Peninsula in Russia, and the adjacent portions of Russia between Finland and the White Sea.

The collections made during the present survey are given in Table II.

TABLE II.

Collections of Diprion polytomum *made in Finland in 1938.*

Locality*	Date	Number of larvae	Collecting place or period and remarks
Turko to Salo	30 June	3	2 places
Tuusala	4 July	2	
Harviald	4 July	4	
Nokia	5 July	4	
Kangasald	6 July	1	
Sammalisto	6 July	2	
Hoertsaenae	6 July	6	
Pohjaslahti	7 July	1	
Kemruu	7 July	3	1 female
Petaejavesi	7 July	2	2 places
Saarijaervi	7 July	5	
Ylipaepae	8 July	1	1 female
Kelloukylae	9 July	4	
Pallastunturi	12 July	108	1 female
	9–23 August	8,205	400–500 m.
		44	Red form
	9 Aug.	20	Tree line
	10 Aug.	13	Above line
Salla†	14–15 July	86	4 places
	30 July–4 Aug.	1,559	
Kuusamo†			
Ouupusaari Island	17 July	4	
Kuusamo to Maauselke	18 July	54	3 places
Maauselke to Oijusluoma Lake ...	18 July	35	2 places
Kuusamo to Rukatunturi	21 July	58	3 places
Kuusamo to Juurikavaara	20 July	65	4 places
Juurikavaara	29 July–12 Aug.	3,046	
Rakatunturi	29 July–12 Aug.	3,028	
Lake Area South Finland			
Kuhmoinen	25 Aug.	19	
Jyvaskyla	26 Aug.	43	9 hours
Pieksaemaeki	27 Aug.	50	7 hours
Kuopio†	28 Aug.	0	4 hours
Heinaevesi	29 Aug.	10	8 hours
Savonlinna	30 Aug.	5	4 hours
Puumala...	31 Aug.–2 Sept.	24	
Mikkeli	3 Sept.	56	4 hours

* The underscored localities and areas are located on the outline map (p. 151).
† *Diprion polytomum* had been previously taken at this place.

Between 4th and 9th July, while proceeding north from Helsingfors to Tornio via Rampere, Drs. Bergold and Kangas found *polytomum* larvae in small numbers at 13 of the 22 places where collecting was attempted between Helsingfors and Oulu.

Pallastunturi, which is a little north of latitude 68° in north-western Finland, is similar to the Ounistunturi area, but it is nearer the tree line in this mountainous area. The larval development was more retarded here than in any of the other areas where large-scale collecting was attempted. On 12th July the larvae were mostly first instars with a few second and third instars. One larva was found at the tree line (500 metres), but larvae were more numerous at a lower elevation. Between 9th and 23rd August Dr. Bergold collected 8,205 typical and 44 red full-grown larvae, from which 5,381 and 21 cocoons, respectively, were obtained. The collections were made between elevations of 400 and 500 metres. The maximum number of larvae found on any tree was 38.

Thirteen larvae were collected on 10th August at Pallastunturi, on four stunted *Picea excelsa ? brevifolia* trees on a very exposed and windy place above the tree line, one kilometre from the nearest normal spruce trees. The branches of these trees were lying on the ground in the grass. It was impossible to estimate their age.

Salla is in eastern Finland, about 30 miles north of the Arctic Circle, just south of latitude 67°. The topography about Salla is rolling or mountainous with the spruce trees well spaced and with their branches descending to the ground. This locality as well as Kuusamo is particularly interesting, because both are situated in an area that escaped the glaciers. Here occur many relic insect species which are not found elsewhere in the world. The parasites of *Diprion*, especially of *D. polytomum*, should be particularly interesting here.

On 14th and 15th July the larvae were mostly third instars. Between 30th July and 4th August Dr. Bergold collected 1,559 larvae, from which 937 cocoons were obtained. Although the larvae were not numerous, larger numbers could have been taken if the collecting had been begun earlier.

Kuusamo is in eastern Finland, 40 miles south of the Arctic Circle, just south of latitude 66°, in the heart of a lake area. The topography is much the same as at Salla. It is in the centre of an enormous spruce area. There are many good places for collecting, but they are quite inaccessible. The larvae were more abundant than at Salla. The stage of development was much the same, the larvae being mostly third with a few fourth and fifth instars. Between 29th July and 12th August Dr. Bergold collected 6,074 larvae, from which 3,644 cocoons were obtained. The general collecting was begun too late for obtaining the number of larvae otherwise possible.

Between 25th August and 3rd September Mr. Conde collected larvae at seven of eight areas visited in the lake region of southern Finland. The forests of this southern lake area are predominantly pine in which spruce plays a secondary rôle. A few small areas of pure spruce were noted. The pine occurs principally along the warm, sun-swept, stony lake and river banks, whereas the spruce occurs as an understory in the pine forest, on rocky outcroppings of hills, as single trees, and in the shady areas less exposed to the sun. Except where spruce is predominant, the islands are relatively free of *polytomum* larvae. Generally speaking, the habitat is not at all suitable for the European spruce sawfly. At Kuopio, although *Diprion polytomum* had been taken previously, Mr. Conde was unable to find any, perhaps because the woodlands that he visited were overrun with ants.

Northern Finland is a one-generation area while southern Finland is a two-generation area.

LITHUANIA.—The area of Lithuania, including the Memel District, is 56,100 square kilometres. There are 9,000 square kilometres of productive forest land, of which 36·5 per cent. is in spruce. The country is relatively flat, the highest point reaching 234 metres above sea level. The forests take on a more central European aspect. Pure spruce stands are rare. The spruce is generally mixed with deciduous trees, the shade of which is not favourable for the development of the sawfly. Between 24th and 26th July, 33 larvae were collected at four places, Praveniškes, Pagiris, Paldiškiai bis Skriandziai, and Alitu. Mr. Conde stated that the insect had never been reported in the literature as found in Lithuania. The area in Lithuania devoted to spruce is not a large one. It is entirely in the two-generation area.

Latvia.—The area of Latvia is 65,700 square kilometres. There are 17,472 in forest land, of which 4,280, or 24·5 per cent., are in spruce. The topography varies from flat to hilly. The highest point (Mt. Gaizen) is 310 metres above the sea level. There are many low-lying and swampy areas through which brooks and rivers flow. Two generations of *Diprion polytomum* occur. Larvae may be found on forest edges and where spruce occurs on extensive wet meadows. The hilly Livland area (" Livland-Switzerland ") is a fine spruce area, but it is too dry for *polytomum* to occur in appreciable numbers. During July 392 larvae were collected in five centres, from which 250 cocoons were obtained. Liel-Renda Forstei, Kabile Forstei, Briezi, Ligatne bis Ieriki, and Vijciems were added to the distribution records of this insect in Latvia.

Estonia.—The area of Estonia is 47,549 square kilometres, of which 9,300 are productive forest land, and of this 2,790, or 30 per cent., are in spruce. This country offered the best opportunities for collecting of any of the three eastern Baltic countries. The Estonian country is more or less rolling, the highest point being Munnamagi, 316 metres above sea level. There are many rivers and brooks. As far as is known *Diprion polytomum* had not been previously recorded from this country, but in this survey larvae were collected from the following places: Esna, Tueri, Tueri bis Paide, Tueri bis Kolu, Loodi, Abia, Alu (Rapla), Kolu, Paeinurme, Paedanicku bis Joikuelae, Paeinurme bis Korru, and Prokuni. Larval collections, mostly of the second generation, totalled 6,768, from which 4,240 cocoons were obtained. The daily average number of second-generation larvae collected was about the same as that in central Europe. This average was from 150 to 200 larvae per man-day. The larvae seem to be more numerous along the water courses than elsewhere.

Conclusions.

The principal contribution of this survey was greatly to extend our knowledge of the distribution of this insect in Europe, to open up an extensive new area for parasite collection, and to secure some material with which to commence a study of the parasites of the European spruce sawfly in the Scandinavian and eastern Baltic countries.

Summary.

Since 1930 the European spruce sawfly (*Diprion polytomum*) has caused severe damage in eastern Canada and is a meance to the spruce woodlands in the north-eastern part of the United States. In 1938 under a cooperative arrangement with the Division of Entomology, Canadian Department of Agriculture, and the Farnham House Laboratory, Imperial Institute of Entomology, England, which were to continue their collecting in the central European area for the recovery of natural enemies, the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, made a survey of the Scandinavian and eastern Baltic countries to extend the knowledge of the distribution of the sawfly; to discover, if possible, better or equally as good collecting grounds, where new species of parasites might be found; and to obtain additional information regarding the better known species of parasites. The most favourable habitats of the sawfly are found in the one-generation areas under conditions which provided a maximum of sun-heat, moisture, and shelter, near to the upper limits of spruce growth. The least favourable habitats are the drier, less humid places, especially in the two-generation areas. The sawfly was found everywhere on spruce, from the German-Danish border in Denmark and in southern Norway to the northernmost spruce forests of Sweden, and from far above the Arctic Circle in Finland southward through the eastern Baltic countries of Estonia, Latvia

and Lithuania. The range of distribution covered in this survey was from approximately latitude 55° in Denmark and Lithuania to latitude 68° 45′ in Finland. This includes most of the Scandinavian Peninsula, Fennoskandia, and the eastern Baltic countries. Spruce comprised from 25 to 40 per cent. of the productive forest land of this large area. Large collections of the European spruce sawfly were made in Sweden and Finland for the Canadian Division of Entomology.

Acknowledgments.

The writer expresses his appreciation for the assistance received from Dr. Gernot Bergold and Mr. O. Conde. Dr. Bergold took the photographs used in this paper.

The results of an undertaking of this sort are materially affected by the assistance and suggestions received from entomologists, foresters and scientists of the various countries concerned. It is impossible to thank everyone who actively cooperated. The writer would particularly thank the following who, although not at all optimistic about the outcome of the survey, extended every possible courtesy and facility to assist him in obtaining data concerning the sawfly.

Professor Dr. Mathias Thomsen, Den Kgl. Veterinaer og Landbohøjskole, København, Denmark, made all arrangements for visiting the forests and the museum and kindly translated Borries' published observations on *Lophyrus hercyniae*.

The Norwegian Department of Agriculture and Dr. Eyrind Johannessen, Secretary of the Office of Forestry, made the arrangements and gave assistance for visiting the forests in the vicinity of Oslo, Norway.

Professor Dr. Ivar Trägårdh and his assistant, Dr. V. Butovitsch, Statens Skogsförsöksanstalt, Experimentalfältet, Sweden, arranged their work in the north so that the writer was able to accompany them to Pajala, Norrbotten, and become acquainted with travelling conditions. Jaegmaestare Westman of Lycksele made arrangements for the trip from Lycksele to Taerna, and Mr. Robert Bengtssen, his assistant, accompanied the writer on this trip.

Professor Dr. O. Heikinheimo, Director Forstwissenschaftl. Versuchsanstalt, Helsingfors, Finland, took a deep interest in the work, and his assistant, Dr. Kangas, Forest Entomologist, acquainted Dr. Bergold with the likely areas for finding *polytomum* in the north of Finland.

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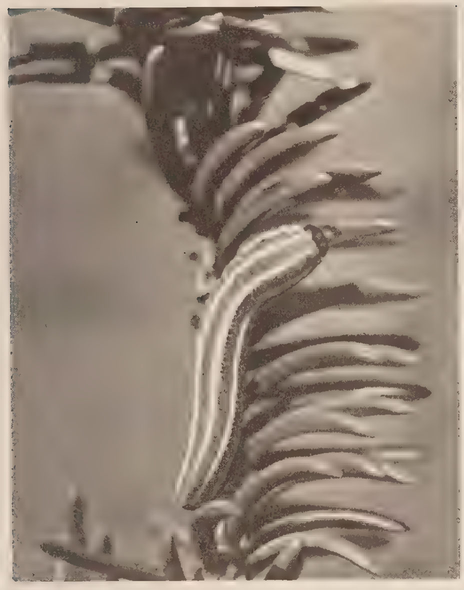

Fig. 1. *D. polytomum*, Htg. Dorsal view of full-grown larva.

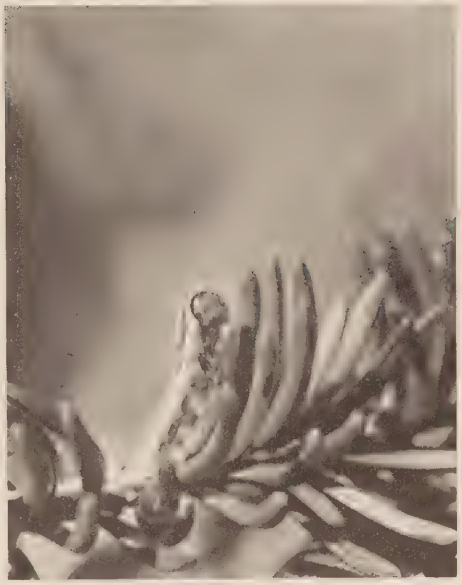

Fig. 2. *D. polytomum*, Htg. Characteristic feeding position of full-grown larva.

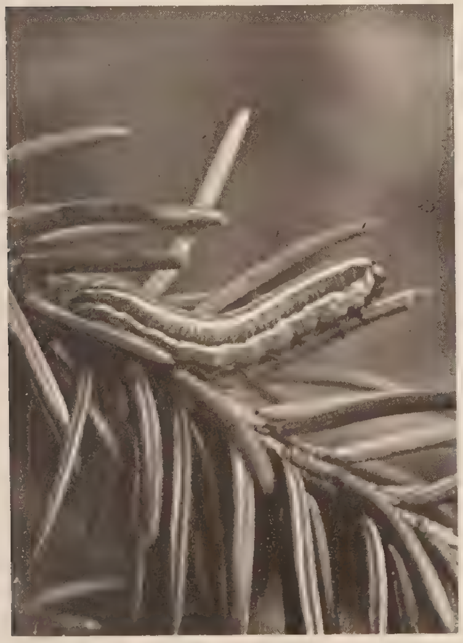

Fig. 3. *D. polytomum*, Htg. Lateral view of full-grown larva.

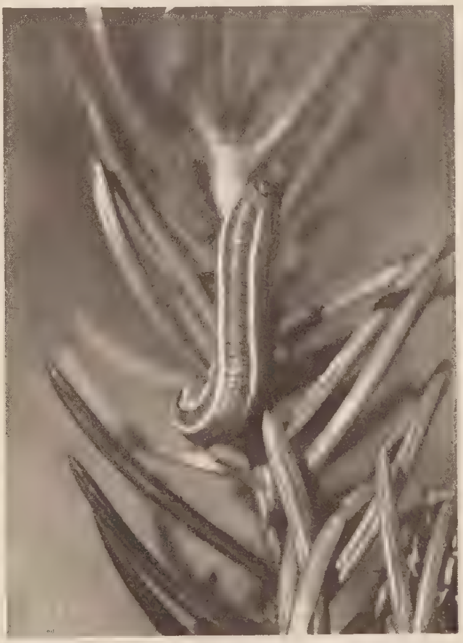

Fig. 4. *D. polytomum*, Htg. Full-grown larva, salmon-red colour.

THE SUMMER HOSTS OF *APHIS FABAE*, SCOP.

By Margaret G. Jones, M.A.

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Introduction.

Aphis fabae, Scop., has been recorded from a large number of host plants. Theobald (1927), Franssen (1930), and Börner and Schilder (1932), have given long lists of plants on which it has been found. Mordwilko (1907) transferred apterous females of *Aphis euonymi*, F. (a synonym of *A. fabae*) from *Euonymus* sp. to *Rumex maximus*, and from *Arctium lappa*, *Rheum* sp. and *Rumex maximus* back to spindle (*E. verrucosus*) and *Viburnum opulus*, obtaining successful colonies in every case. Other workers have recorded further results from transference experiments. There is, however, no record of any host preferences, although Davidson (1921) noted that colonies thrive better on certain plants, *e.g.* bean, than on others.

In the following experiments, which were carried out at the Entomological Field Station, Cambridge, it was hoped to further the results obtained from pure transference by allowing spring alatae to colonise a number of different summer host plants within a restricted area, so as to determine whether there was any preference. If some plants are colonised more readily than others, they might be used to protect more vulnerable crops. At the same time, the occurrence of biological races on summer hosts might be discovered.

Method.

A number of experimental plots were set up, with summer host plants arranged in a random manner around a central winter host and enclosed by muslin cages. The muslin reduced the light intensity by the same amount in all the cages (5–18 per cent., depending on the intensity). *Euonymus europaeus* and *Viburnum opulus* were the central winter host plants on which the spring colonies were established.

Nineteen small shrubs of *Euonymus europaeus*, 12–18 ins. high, were planted on a clear patch of ground in the early spring, and a few days later the chosen summer hosts were planted around them in a ring with a radius of approximately 18 ins. Eleven of these plots were completed some time before the other eight. The bushes were then infected with fundatrices obtained from *Euonymus* sp. in the Botanic Gardens, Cambridge, or from other spindle trees in the neighbourhood. It was hoped to rear the progeny of one fundatrix only on each winter host, but as there was a high mortality of the introduced Aphids, several had to be placed on the plant to ensure successful colonisation. On one bush only (Plot 1) were all the Aphids definitely descended from one fundatrix.

The summer host plants used were :—*Vicia faba*, *Beta vulgaris* (seed and root crop), *Papaver rhoeum*, *Chenopodium album*, *Rumex obtusifolius* and *Cirsium arvense*. In some cases, one or two of the young plants failed to establish themselves, and on some plots *Arctium lappa*, *Solanum nigrum*, and *Capsella bursa-pastoris* were planted instead of some of the above. Seven small *Viburnum* bushes were planted and surrounded by summer host plants in the same way, but owing to the cold spring, the bushes suffered badly from frost, and only two really established themselves.

When the colonies were sufficiently large and alate nymphs were present, cages were placed around the plants in the plots. The cages were of two types ; 9 consisted of wooden frames 1½ ft. high, and 17 were 3 ft. high, the muslin being attached to 4 ft. stakes which had been driven 1 ft. into the ground. The plots were visited frequently, and the plants kept sufficiently small to ensure that they did not touch one another, although in a few cases, migration by apterae took place as a result of contact before the plants could be cut back. When either sufficient numbers of plants had been attacked, or when there were no more Aphids on the central plant, the plant shoots bearing the Aphid colonies were placed in bottles in 70 per cent. alcohol and removed for counting at a later date. Although the weather in May was unfavourable for the development of Aphid colonies, it improved during June and the beginning of July, when Plots 1–18 were working, but towards the middle and end of July, there was less sunshine and more rain, so that conditions for Plots 19–26 were less favourable for Aphid development.

Colonisation of the Summer Host Plants by Alatae arising from Euonymus europaeus.

A record was kept of the dates on which the summer host plants around the central winter host were colonised by alatae from the central plant.

(*a*) *Plots* 1–11. (Plot 6 gave no result.)

TABLE I.

The Order of Colonisation on the Summer Host Plants in Ten Plots (*Plots* 1–11).

	Bean	Beet Seed	Dock	Poppy	*Chenopodium*	Thistle	*Solanum*
Total number of plots with :—	10	10	10	8	10	10	2
Total number colonised	10	9	8	6	9	5	0
Order in which plants were colonised in the plots : No. colonised :— 1st	10	1					
2nd		8	4	3	1		
3rd			3	3	6		
4th			1		2	4	
5th						1	

The results given in Table I show that bean was the summer host which was colonised first in every plot, although in one case a colony on sugar-beet was recorded on the same date. Sugar-beet seed plants were the next to be infested, while dock and poppy were colonised either at the same time or later. Most of the *Chenopodium* plants bore colonies, while thistle was always the last plant colonised.

(*b*) *Plots* 19–26.

Adverse weather conditions and the presence of Coccinellid larvae and adults, which appeared from the nearby herbaceous border, tended to kill off the initial colonies on the central plant. Bean suffered badly from caterpillar attack early in the season, and the beet plants, with the exception of the one in Plot 22, were all root crop plants.

TABLE II.

The Order of Colonisation on the Summer Host Plants in Eight Plots (*Plots* 19–26).

	Bean	Beet	Dock	Poppy	*Chenopodium*	Thistle	*Arctium*
Total number of plots with :—	8	8	8	6	8	8	4
Total number colonised	6	3	1	3	2	0	1
Order of colonisation : No. colonised :— 1st	5	2		1			1
2nd			1	1	1		
3rd	1	1		1	1		

The results, given in Table II, were less complete than those shown in Table I, but bean was colonised first in five cases, tying in one instance with a beet plant. Beet and poppy were colonised three times, while the other plants showed few infestations. Thistle remained free from Aphids.

(*c*) *Second Colonisations on Plots* 1–5, 8, 9 *and* 25.

As there were flourishing colonies on the spindle bushes, the plants in these eight plots were left under the cages for further colonisation after the removal of the first formed colonies on the peripheral plants. As most of the bean plants had been removed with the first colonies, those parts left did not compare favourably with the other plants, and in one case (Plot 2) a small bean plant, 6 in. high, was planted instead of the one removed. In one plot (5), the range of host plants was changed to *Chenopodium album*, *Solanum nigrum*, *Arctium lappa* and *Capsella bursa-pastoris*, in order to give a different choice.

TABLE III.

The Order of Colonisation in Eight Plots for the Second Time (*Plots* 1–5, 8, 9 *and* 25).

	Bean	Beet Seed	Dock	Poppy	*Chenopodium*	Thistle	*Solanum*	*Arctium*	*Capsella*
Total number of plots with :—	4	7	7	5	8	7	2	1	1
Total number colonised	4	6	6	4	6	3	1	0	0
Order of colonisation : No. colonised :— 1st	4	5	1		2				
2nd			4	2	4				
3rd		1	1	1		3	1		
4th				1					

The results in Table III show that all the available bean plants were colonised first, tying in three cases with beet (seed). Beet was colonised first in two other plots, which lacked bean, while dock, *Chenopodium* and poppy were next infested.

Thistle bore either a very small colony, or none at all. In Plot 5 only *Chenopodium* bore a colony.

Colonisation of the Summer Host Plants by Alatae arising from Viburnum opulus.

Owing to the inability of the *Viburnum* shrubs to support large initial colonies, the results obtained were less complete than from the *Euonymus* plots.

TABLE IV.

The Order of Colonisation of Summer Hosts in Six Plots by Alatae from Viburnum opulus.

	Bean	Beet Seed	Dock	Poppy	*Chenopodium*	Thistle	*Euonymus*
Total number of plots with :—	6	6	6	6	5	5	4
Total number colonised	5	4	3	3	1	2	0
Order of colonisation : No. colonised :— 1st	5	2					
2nd		2	1	2			
3rd			2		1	1	
4th				1			
5th						1	

Table IV shows the same order of colonisation as found in the *Euonymus* plots :—(1) bean, (2) beet, (3) dock, poppy and *Chenopodium*, and (4) thistle. In one case (Plot 13) beet only was attacked.

Plot 18 was left to give a second result, with colonisations in the order :—(1) beet, (2) *Chenopodium*, (3) poppy and dock. Thistle was not attacked.

TABLE V.

The Combined Results from the Colonisation of all the Plots.

	Total No. of plants	Total No. colonised	Order of colonisation				
			1st	2nd	3rd	4th	5th
Bean	28	25 89%	24		1		
Beet	31	22 70·9%	10	10	2		
Dock	31	18 58%	1	10	6	1	
Poppy	25	16 64%	1	8	5	2	
Chenopodium ...	31	18 58%	2	6	8	2	
Thistle... ...	30	10 33·3%	2		4	4	2
Arctium ...	5	1	1				
Solanum ...	2	1			1		

Table V gives the combined results from the four series of experiments, and shows that both the percentages and the times of colonisation of the summer host plants point to a preference in the order (1) bean, (2) beet (3) dock, poppy and *Chenopodium*, (4) thistle. Owing to the small number of trials on *Arctium* and *Solanum*, their results are not significant.

Secondary Migration by Apterae and Summer Alatae.

Further observations were made on three plots in which the central winter host, *Viburnum opulus*, died after only one of the surrounding summer host plants had been infested. Colonisation of the remaining summer hosts took place as a result of migration, chiefly of apterae, from the first one, although the plants were not touching.

Beet was the infested summer host in one plot (13). After one month all the other summer hosts were colonised from it. In the other two plots (15 and 16), bean was the infested summer host. On the sixteenth day after the founding of the bean colonies, apterae were observed migrating in all directions, and colonies were started on all the remaining plants.

A certain amount of colonisation by apterae was unavoidable in some of the other plots: *e.g.*, apterae dropped down from bean on to dock and *Chenopodium* (Plot 3); poppy leaves touched one *Euonymus* leaf so that some Aphids migrated across in two plots (8 and 9).

It was noted that if apterae fell from their original host plants, they walked up the nearest available object and seemed to have no powers of selection until they had extended their probosces to test the food value of the object.

The Total Number of Aphids on the Summer Host Plants.

The total numbers of Aphids produced in the colonies founded on the summer host plants show great variation from plot to plot, and from plant to plant. Nevertheless the numbers confirm the general order of preference: (1) bean, (2) seed beet, (3) dock, *Chenopodium* and poppy, (4) thistle. This order was found both in the *Euonymus* and *Viburnum* cages (Tables VI and VII). Where the beet plants were crop plants, the colonies were much smaller than on the seed plants (*cf.* 23 with 5).

The number of Aphids in any colony is influenced by several uncontrollable factors, such as (*a*) the number of alatae settling on the plant, (*b*) the date of the founding of the first colony, (*c*) the age of the colonies, (*d*) the size of the plant, for in some cases beet seed plant was much branched, and consequently offered a larger surface area than any of the other plants (plots 5, 8 and 9), (*e*) weather conditions, and (*f*) the proportion of parasites and predators. It was therefore not possible to work out any mathematical relationship for the population of Aphids on the different summer host plants.

TABLE VI.

The Total Numbers of Aphids recorded from the Summer Hosts.

(The lower figure for each plant gives the number of alatae counted. The approximate age of the colony in days is given underneath the figures for each plant.)

Plot	Bean	Beet	Dock	Poppy	*Cheno-podium*	Thistle	*Arctium* or *Solanum*
1	6224	3179	990	826	31	20	*
	61	41	8	15			
Age	12	9	9	9	5	1	
2	2051	1125	1685	*	155	41	*
	189	94	94		24	12	
Age	10	4	4		2	1	
3	6358	295†	2+110†		1+13†		*
	24		2		1		
Age	9	2	2		1		
4	5792	3974	543	105	387		*
	58	86	48	8	17		
Age	11	10	9	9	9		
5	4663	7357	77	413	66	2	*
	13	105	3	42	3	1	
Age	11	11	7	7	7	1	
7	2765	163	21	*	265	20	*
	3	6	1		8	2	
Age	24	21	18		14	1	
8	226	781†	69	463†	66†	8†	*
	1		1	4			
Age	16	3	1	2	1	1	
9	965	1375	420	559†	238		*
	11	67	6	29	3		
Age	11	10	2	10	6		
10	5718	130		634	1308		
‡	146	5		93	110		*
Age	31	2		7	7		
11	249						
							*
Age	10						
19	37						
	4						
Age	6						
20	2451	51					
	21	3					
Age	6	1					
21	15						
							*
Age	7						
22		32					
		4					*
Age		1					

* = No plant.
† = Colony formed partly by apterous migration.
‡ = Plots where counts include winged females of the second summer generation.

TABLE VI—*continued.*

Plot	Bean	Beet	Dock	Poppy	*Cheno-podium*	Thistle	*Arctium* or *Solanum*
23	14202	27	8	30	1358†		8 (*Arctium*)
‡	129	6	3	3	29		1
Age	26	1	3	1	4		1
24	8			103	80		
	1			2	2		
Age	1			11	7		
25	1190						
	1						
Age	15						
1b	*	4790†	9	48			*
		49		1			
Age		7	1	7			
2b	2666	8643	2272	*	5159	48	30 (*Solanum*)
	12	58	19		76	2	2
Age	7	7	7		7	1	1
3b	6273	233	584	323	1777		*
	61	4	3	7	9		
Age	7	4	7	4	7		
4b	3886	3012	666	137	433		*
	71	53	27	7	39		
Age	4	4	4	1	4		
9b	*	5184	458	422	326†	2	
		75	3	29	23	1	
Age		10	10	10	10	<1	
25b	*		26†	*	14†		*
Age			6		1		

*=No plant. †=Colony formed partly by apterous migration.
‡=Plots where counts include winged females of the second summer generation.

TABLE VII.

The Total Numbers of Aphids recorded from Summer Host Plants, Viburnum opulus *as the Central Plant.*

(The arrangement is as for Table VI.)

Plot	Bean	Beet	Dock	Poppy	*Cheno-podium*	Thistle
14	Colony died out	452	Colony died out	9		
		1				
Age		14		—		
17	4656	352	173	2162	*	2
	15	6	6	13		1
Age	14	9	9	9		>1
18	2692	625	21	17	612	4
‡	174	70	6	7	74	4
Age	12	11	7	1	7	>1
18b	218	993	55	43	840	
	6	21	5		19	
Age	—	7	1	1	6	

The large size of the colonies produced by the migration of apterae can be seen from Table VIII. Again bean bore the largest number of Aphids, even in Plot 13, where the colony had been established for a shorter time than the one on beet (seed).

TABLE VIII.

The Total Numbers of Aphids produced as a Result of the Migration of Apterae and Summer Alatae.

(The arrangement is as for Table VI.)

Plot	Bean	Beet	Dock	Poppy	*Chenopodium*	Thistle	Spindle
13	4328	1812	568	54	733	4	3
	9	3	2	1	1		1
Age	<8	22	<8	2	<8	1	1
15	4516	16	234	777	824	13	
	8						
Age	16	>1	>1	>1	>1	>1	
16	10305	2062	not recorded	1846	338	31	134
	20						
Age	16	>1	>1	>1	>1	>1	>1

Discussion.

The results from these plots indicate that the spring alatae of *A. fabae* show a preference for bean when given a choice of summer host plants. Sugar-beet seed plants are colonised next and are more liable than crop plants to Aphid attacks. This ready colonisation of seed plants early in the year is also found in the field. Poppy, dock and *Chenopodium* appear to be colonised in no very definite order. Thistle on the other hand, is not so frequently infested and does not support a large colony in any of the plots.

When a flourishing colony has been founded by a spring migrant, a large number of plants in the neighbourhood can be further colonised by the apterae which may fall off and walk up a hitherto uninfected plant. When the original host becomes overcrowded, or is in a poor condition, the apterae migrate actively in search of a new host. This migrating habit of apterae is important in fields where a large number of similar host plants are growing together. In years when infestation of beet root crops has been slight, small circular patches of heavily infested plants have been observed in July. It seems probable that the patches arise from the central colony founded earlier in the season by a single primary migrant from a winter host. Colonisation of plants by apterae appears to be entirely at random. The results give no evidence of the presence of biological races on the different summer host plants, as all appear to be liable to attack from the same winter host. Simple transference experiments show that *A. fabae* readily accepts a large number of host plants, but it does thrive better on certain plants, such as beans and sugar beet. Davidson (1921) found that a single apterous viviparous female, placed on bean, produces more progeny in a given time than a similar one on peas, mangolds, sugar beet, red beet, and poppies under similar conditions.

The effect of parasites and predators depends largely upon the relative numbers present, for a small colony of Aphids is killed off, while a larger one is not. It is unfortunate that the two summer host plants apparently preferred by the spring migrants should be crop plants, so that the other plants cannot be used to protect them in any way. It may be possible, however, to protect sugar beet seed plants from heavy initial infection by planting the headlands of the fields with bean and removing them when colonised by the Aphid. This should help to reduce the cost of spraying whole fields of beet seed.

Summary.

1. When spring migrants of *Aphis fabae*, Scop., from *Euonymus europaeus* and *Viburnum opulus* are given a choice of summer host plants enclosed by a muslin cage, they colonise bean first and then sugar beet. Dock, poppy and *Chenopodium* are colonised in no very definite order, but thistle is the last plant to be infested.

2. Further infestation of surrounding plants takes place rapidly by means of apterae, which migrate actively and colonise plants at random.

3. The total number of Aphids on the summer host plants is of the same order as the times of colonisation.

4. The effect of parasites and predators is proportional to the numbers present and to the size of the colony.

5. The results do not indicate the presence of biological races on the chosen host plants.

I should like to thank Mr. F. G. W. Jones, of the School of Agriculture, Cambridge, for his help in preparing the ground for the plots and in rearing some of the plants, and Dr. W. H. Thorpe for his criticism.

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ON A NEW SPECIES OF *EPHIALTES* (HYM., ICHNEUMONIDAE) PARASITISING THE CODLING MOTH.

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Department of Entomology, British Museum (Natural History).

In 1939 I dealt with two species of *Ephialtes* which parasitise the codling moth, *Cydia pomonella*, L., namely *E. caudatus*, Ratz., and *E. crassiseta*, Thoms., and showed how they differed from *E. punctulatus*, Ratz. (=*extensor*, Tasch.) with which species they had formerly been confused. During 1940, F. J. Simmonds, of the Imperial Institute of Entomology, sent to the British Museum a series of a species of *Ephialtes* bred from this same host in the south of France. This is a new species, and it was previously known to me only from a single female which had been bought by D. S. Wilkinson from O. Schmiedeknecht, who had incorrectly named it *Pimpla roborator*, F. In fact, this new species does not belong to the same species group as *Ephialtes* (*Exeristes*) *roborator*, F., Grav. (=*Pimpla roborator*, F., Schmied.), which is a well-known parasite of the European Corn Borer (*Pyrausta nubilalis*, Hb.) and also parasitises many other hosts.

As there has been considerable confusion in the synonymy and interpretation of *E. roborator*, F., it seems advisable to give notes on the relevant type specimens seen by me. It has been impossible to find the type of *Ichneumon roborator*, F. Gravenhorst's interpretation of this very variable species has therefore been taken. The description given by Schmiedeknecht in his *Opuscula Ichneumonologica* is adequate for the recognition of the female ; the male is very distinct, having a tubercle in the middle of the clypeus, a character unknown in any other described European species. *Pimpla cicatricosa*, Ratz., which is given by Schmiedeknecht as a synonym of *P. roborator*, F., is a distinct species. It is an *Ephialtes*, which parasitises various species of *Sesia* ; it differs from the new species bred from the codling moth not only in colour, but also has the abdomen more deeply and more sparsely punctured and the ovipositor a little shorter than the whole body. From *E. roborator*, F., it differs in the much more elongate form and the sparser puncturing of the abdomen. Thomson's "*Pimpla roborator*, F." is *E. cicatricosa*, Ratz. (For notes on these species see Thomson, *Opuscula Entomologica* :—*E. cicatricosa*, Ratz., under *P. roborator*, p. 753 ; *E. roborator*, F., under *P. punctata*, p. 2126.)

The synonymy of *Ephialtes* (*Exeristes*) *roborator*, F., in so far as the types have been examined, is as follows :—

Ephialtes (*Exeristes*) *roborator* (F.).

Pimpla roborator, vars. 1 and 2 Grav. (1829) ; *brevicornis*, var. 2 Grav. (1829) (♂) ; *flavipennis*, Rudow (1883) ; *nodosa*, Rudow (1883) ; *robusta*, Rudow (1883) ; *schmiedeknechti*, Kriechb. (1888) ; *punctata*, Thomson (1895) ; *brachycera*, Thomson (1895) ; *blattifera*, Tosq. (1896).

The single specimen standing under the name *P. brachycera* in the Thomson collection is only a small weak specimen of *E. roborator*, F. ; after examining a long series of the latter species, the author does not believe that the characters given by Thomson for separating his *P. brachycera* from his *P. punctata* hold. The specimen of *P. brachycera* has the ovipositor exserted.

Morley's description of *Pimpla roborator* in his British Ichneumons obviously refers to a mixture of species. In the British collection in the British Museum, in which the Pimplinae had been arranged by Morley this was so, though subsequent additions may have been made. The series included specimens of *E. crassiseta*, Thoms., and *E. terebrans*, Ratz., from Britain and also Continental specimens of *E.*

roborator, F., sent to the Linnean Society collection by Gravenhorst and later presented to the British Museum. Two specimens from the Lyle collection named *P. roborator*, F., were *E. cicatricosa*, Ratz. The author has seen no specimen of *E. roborator*, F., from Britain.

Superficially, the new species bred from the codling moth bears some resemblance to *E. ascaniae*, Rudow (=*sanguinicollis*, Brauns) on account of the strongly red marked thorax. Structurally it is very closely related to *E. crassiseta*, Thoms., which is also a parasite of *Cydia pomonella* as well as of various species of *Sesia*, and, to a less degree, to *E. longiseta*, Ratz. (=*haemorrhoidalis*, Tschek.), originally bred from *Grapholitha pactolana*, Zell. However, *E. ascaniae*, Rudow, belongs to quite another species group of this large genus and is conspecific with the genotype of *Apistephialtes*, Seyrig, which Perkins (1940) synonymised with *Ephialtes*, Grav. ; it is most closely related to *E. tenuiventris*, Holmgr., nec auctt. (=*antefurcalis*, Thoms.), both these species having the transverse median vein of the front wings usually received near the apex of the median cell, though it may very rarely be interstitial with the basal vein, and the unpunctured apical area of the central abdominal segments unusually broad. *E. ascaniae*, Rudow, has been described under various names due to the collapsing of the abdomen in specimens killed too soon after emerging and before the integument had properly hardened. The abdomen of a large number of species of this genus is spindle-shaped in life and also after death, if the specimen has become properly hardened, but if killed when freshly emerged, the tergites curl round ventrally and the abdomen appears parallel-sided. If the abdomen of a specimen that has collapsed is placed in weak caustic potash, the integument swells and will then assume the spindle shape of the abdomen in life. This collapsed condition is a great nuisance to the systematist, for the relative length to breadth of the segments is an important specific character. A number of species have been described as distinct which differ only in the spindle-shaped or parallel-sided abdomen, *e.g.*, *Ephialtes* (*Epiurus*) *punctiventris*, Thoms., is only *E.* (*E.*) *brevicornis*, Grav. (=*Pimpla* (*Epiurus*) *nigriscaposa*, Thoms.) in which the abdomen has collapsed.

I wish to thank Mr. R. A. Cushman, of the United States Bureau of Plant Quarantine. From notes that I sent him, he informs me that the species described below is distinct from any species known to him from North America.

Ephialtes cydiae, sp. nov.

♀. *Head* : Temples slightly narrowing directly behind the eyes ; antennae 27 to 30 segmented, usually with 28. *Thorax* : pronotum punctured and striate in the hind angles ; mesonotum rather closely, distinctly, though rather finely punctured, densely punctured anteriorly on the median lobe ; mesopleura anteriorly and ventrally, with the mesosternum, distinctly though sparsely punctured, the speculum polished ; scutellum a little more coarsely, but more sparsely and shallowly punctured than the mesonotum ; propodeum coarsely and rather deeply punctured dorsally lateral to the two longitudinal carinae which are strong, the area between the carinae shallowly rugose punctate becoming smoother in the middle, the declivous apical part of the propodeum with two circular unsculptured polished areas divided by a longitudinal carina which has two or three longitudinal rugosities on each side, before these areas the sculpture of the dorsal part of the propodeum becomes irregularly trans-striate ; metapleura dorsad much more sparsely, more finely and shallowly punctured than the propodeum, becoming almost smooth above the hind coxae ; metathoracic spiracles sub-circular ; the hind legs as in *E. caudatus*, Ratz. (*cf.* Perkins, 1939, figs. 2b & 3b). *Abdomen* : 1st tergite about $1\frac{1}{3}$ times as long as apically broad, the central area not strongly raised, evenly closely punctured except laterally apically where the punctures are usually sparser and the ground sculpture is sometimes coreaceous, the extreme apex of this segment is polished ; the remaining tergites very closely punctured except on the tubercles of segments 3 to 5 where the punctures are a little sparser ; the punctures of tergites 5 to 7 become progressively finer ; the apical unpunctured areas of tergites 2 to 5 are narrow, occupying about $\frac{1}{7}$ of the segment ; ovipositor sheaths which are clothed with rather long hair, are about 1·2 times as long as the whole body and about $2\frac{1}{2}$ times as long as the hind tibia+tarsus. *Wings* : fore wings with the transverse median interstitial with the basal, or received in the extreme base of the discocubital cell ; the transverse median of the hind wings angled a little above the middle.

Colour : Antennae black : body black with the maxillary palpi, the labrum, the hind angles of the pronotum, the tegulae, the extreme apex of the scutellum and the post-scutellum very pale-yellow or white ; the hind angles of the pronotum before the white apex, four broad lines on the mesonotum (the lateral ones extending from the notauli to, or a little beyond, the tegulae, and the other pair running along the notauli to coalesce in a square spot on the disc), the scutellum, the post-scutellum, the prepectus except for a lateral triangular fuscous mark, the callus before the front wings, the mesopleura below a line running from the upper end of the epicnemia to the punctiform fovea and the mesosternum red ; the abdomen sometimes marked with red laterally or (as in the specimen from Germany) with the segments reddish, the apical smooth margins of the segments only being black : legs with the coxae red, the fore trochanters red, white anteriorly and apically, the middle and hind trochanters red, white apically the tronchantelli white, red posteriorly ; the femora red, white apically ; the tibiae dirty white, red beneath, of the middle and hind legs fuscous externally and with a fuscous spot posteriorly towards the base and at the apex which is also marked with red before the fuscous spot ; the tarsi red, the segments narrowly fuscous apically. Wings usually lightly infumate, the veins fuscous, the stigma fuscous with the centre testaceous.

♂. Differs from the ♀ (other than in sexual characters) in having the temples a little broader behind the eyes, the antennae and legs a little more elongate and in the colour. The mesonotum and mesopleura are entirely red, the propodeum is marked with red, the front and middle legs are white with the femora and tibiae weakly marked with red, the hind legs are red with the trochanters, the trochantelli, the tibiae except in the apical $\frac{1}{4}$ and a very indistinct spot towards the base, and the hind tarsi except for the extreme apices of the segments and the 5th segment which are fuscous, white. The genital claspers are strongly elongate.

Type : France : Var ; Lavandou ♀, x.1939 (*F. J. Simmonds*). (E.1.1.).

Host : *Cydia pomonella*, L.

Allotype : France : Gard ; Aubord, ♂, 6.vi.1939 (*F.J.S.*).

Other Material examined : France : Gard ; Aubord, 4 ♂♂, 6.vi.1939 (*F. J. S.*) ; Var ; Lavandou (*F.J.S.*), 17 ♀♀ with labels bearing the following experiment numbers :—E.1.2 ; E.1.4 ; E.1.5 ; E.1.6 ; E.1.7. ; E.1.8 ; E.1.10 ; E.1.11 ; E.1.12 ; E.1.13 ; E.1.14 ; E.1.14 ? ; E.1.15 ; E.1.16 ; 40 A 9 ; 17 B 2 ; 25 C 18 ; Germany, 1 ♀ (*O. Schmiedeknecht*).

All the above material has been deposited in the British Museum.

E. cydiae differs from *E. crassiseta*, Thoms., in having the thorax strongly red marked, the legs more conspicuously marked with white, the hind angles of the pronotum more distinctly and more deeply punctured, the propodeum with the central carinae much more distinct and the presence of the central carina on the declivous apical area, the central area of the first tergite less strongly raised, the punctures of the abdomen closer with the smooth apices of the segments a little broader, and the hind femora a little thinner. *E. longiseta*, Ratz., differs from the above two species in having the temples a little widened behind the eyes and very distinctly punctured, the antennae usually 26 segmented, the mesonotum more closely punctured, the mesopleura much more coarsely and closely punctured, with no speculum (*i.e.* with the area in the position of the speculum punctured) and the hairs of the ovipositor sheaths much shorter ; it differs further from *E. cydiae* in having the thorax black with only the extreme hind angles of the pronotum and the tegulae yellow, the legs less conspicuously marked with white and with the femora frequently marked with fuscous, the hind tibiae usually strongly infuscate, sordid white only at the base and the tarsi fuscous, the declivous part of the propodeum weakly sculptured centrally, but with no distinct longitudinal carina, the central area of the 1st tergite more strongly raised and the smooth apical areas of the tergites broader, and the hind femora a little thicker (as in *E. crassiseta*). The abdomen of *E. longiseta* is frequently reddish in part and may be distinctly red with only the smooth apices of the segments black.

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"MOSQUITOES OF THE ETHIOPIAN REGION"—NOTES AND CORRECTIONS.

By G. H. E. Hopkins, M.A.*

One or two errors in "Mosquitoes of the Ethiopian Region" have recently come to light, and several new Culicine larvae have been discovered since the first volume was published. I take this opportunity to correct the errors and to indicate the positions which the newly-described larvae should occupy in the keys. I have not seen most of these larvae and have inserted them in the keys solely from the descriptions.

A number of the mosquitos of which I described the larvae in Vol. I of the monograph were incorrectly determined, but Edwards has already pointed out these mis-determinations (in Vol. III) and I have not thought it necessary to mention them here.

At the request of Mrs. G. R. Cunningham van Someren (formerly Miss E. C. C. Macdonald), I have added her description and figure of the larva of *Aëdes adersi* and her description of that of *Culex adersianus* as an appendix (see p. 178).

Key to Adults of Finlaya (*Vol. III, p.* 120).

A minor alteration is required here owing to the fact that the hind tarsus of *A. fulgens* has only one white ring. The error was pointed out to me by Mrs. van Someren.

In the first part of section 2, insert "one or" before "two white rings."

Key to Larvae of Anopheles (*Vol. II, p.* 51).

Mr. G. R. Cunningham van Someren kindly points out that the larva of *Anopheles kingi* runs down incorrectly in the key (to *A. ardensis*). In section 7 of the key this larva is included among those with the saddle-hair split into less than 5 divisions, whereas in the description (p. 122) this seta is correctly stated to have about 7–9 long branches. Mr. van Someren has checked this point on larvae obtained in Ethiopia, and I have confirmed it on a few of the original larvae.

The following corrections are necessary in the key :—

Sections 18 *and* 19. Delete section 19. At the end of the second alternative in section 18, for "19" read "20."

Section 43. For "*ardensis* and *machardyi* (differences on p. 109)" read "43a." Insert new sections as follows :—

43a. Typical abdominal palmate hairs with filament short and usually blunt......... *machardyi*, p. 109

These hairs with well-developed, long, sharp filament..........................43b.

43b. Outer clypeal hairs much less than half length of inner clypeals.................... *ardensis*, p. 103

Outer clypeals at least about half length of inner ones.................*kingi*, p. 120

A character that I find of great value in distinguishing the three members of the *Neomyzomyia* section of *Myzomyia* which are known from Uganda (*ardensis*, *kingi* and *natalensis*) from any other Uganda Anopheline larvae is not mentioned in the descriptions and is obscured by a slight inaccuracy (for which I must accept responsibility) in fig. 48a. I refer to the marked inward bend (often almost angular) near the base of the inner clypeal setae. This bend seems to be more or less characteristic of the *Eomyzomyia* and *Neomyzomyia* groups ; it is found in *Anopheles nili*, is shown in Evans's figure of *A. wilsoni* (fig. 33a), and there seems to be an indication of it in her figure of *A. cinctus* (fig. 50a). It is not quite accurate to call it an inward bend ; the true position seems to be that the seta first takes a slightly outward and dorsal direction and then bends inwards and ventrally.

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The Larvae of Aëdes longipalpis *Grünberg and* A. fulgens *Edwards.*

In Vol. III, p. 429, the statement is made, on the authority of Mr. C. B. Symes, that the description which I gave (Vol. I, p. 104) of the larva of *Aëdes* (*Finlaya*) *longipalpis* was drawn up from larvae of *A.* (*F.*) *fulgens*. This statement is incorrect : as mentioned in my description, the larvae which I described were from Nigeria and the figure was that published by Macfie and Ingram (1922–23, p. 430) of a larvae from Ofako, near Accra, Gold Coast : *Aëdes fulgens* is not recorded from either of these countries. The error is doubtless due to Mr. Symes having actually sent me larval pelts of *fulgens* and to the assumption having been made that these were the specimens I described, but these pelts were collected (at Mombasa) in December 1937, whereas my volume of " Mosquitoes of the Ethiopian Region " was published in April 1936.

I no longer possess the larvae from which my description of *longipalpis* was drawn up, but I have the slightly-damaged pelts from which two of the specimens of *longipalpis* obtained by Mr. Gibbins at Katoba, western Uganda, and determined and recorded by Edwards (Vol. III, p. 121) were bred. These show the following characters : Head-seta A 4-branched in both, C missing, *d* situated on a longitudinal line between B and the scar of C (exactly as shown in Macfie and Ingram's figure), siphonal index in the less-crushed pelt 3.4, pecten-spines dark-coloured throughout under a low magnification and not appearing blunt (but pale-tipped under higher magnification), spines on margin of saddle coarser than in the figure, which I believe to be slightly inaccurate in this respect (in my description I laid stress on the size of these spines), but not " almost as strong as the pecten-spines." All these characters, except the relative sizes of head-setae B and C (which I am unable to check), and the pale tips of the pecten-spines (an easily-overlooked character) are as described by me in 1936 and not as in the larvae from Lagos and Ibadan described by Edwards.

Mrs. van Someren has kindly sent me a large number of larval pelts and whole larvae of *Aëdes fulgens* from Mombasa. These differ from the larvae of *longipalpis* which I have seen in the following respects : Head-seta A nearly always 2-branched, at least on one side (24 out of 25 specimens), occasionally 3-branched on one or both sides ; B and C usually, perhaps always, sparsely plumose (in a few specimens I cannot be sure of this point) ; *d* rather variable in position, always within the line joining the bases of B and C on the same side, often almost level with the line joining the bases of seta B on the two sides, but sometimes much further back. Siphonal index, in ten whole larvae taken at random, varying between 2.8 and 3.7. The spines on the margin of the saddle are considerably coarser than in my two pelts of *longipalpis*, but the pecten-spines are similar in the two forms.

In several characters these larvae of *fulgens* differ from those of *longipalpis* which I have seen and resemble those described by Edwards as the latter species. They differ markedly from Edwards' larvae in the facts that seta A is always branched and much shorter than B, that seta C is longer and stouter than B, and that the siphon is much longer. The most likely explanation of the puzzle seems to be that the larvae of both *fulgens* and *longipalpis* are variable and that the two forms are indistinguishable in the larval stage. This would not be surprising, for the two forms are very closely related. With regard to the much greater length of head-seta A in Edwards' larvae than in any (of either form) seen by me, it may be noted that in species in which a given seta may be branched or single there is a strong tendency for it to be much longer in specimens in which it is single.

Key to Larvae of Uranotaenia (*Vol. I, p.* 41).

Delete sections 14 and 15 (except the footnote) and substitute the following :—

14. Gills nearly three times length of saddle of anal segment†.........*nigripes* (p. 51)
Gills nearly four times length of saddle...............................*fusca*† (p. 52)

Key to Larvae of Aëdes (*Vol. I, pp.* 95–98).

Delete section 22 and its footnote and substitute :—

22. Head-setae B and C both single or at most double, about equal in length or C much longer than B..23
Either at least one of these setae (usually both) with 3 or more branches, *or* B much longer (and usually much stouter) than C................................28

At end of the first alternative in section 23, after "*longipalpis* (p. 104)" add "and *fulgens*."

Delete sections 29 and 30 and read :—

29. Head-seta B only about half length of C.......................................*adersi*
This seta as long as, or longer than, C...29a
29a. Seta B single (rarely double), much longer and usually stouter than C.........30
This seta with at least 3 branches, not (or but little) longer than C............31
30. Seta C with 2–3 branches..30a
This seta with 5–6 branches...*hirsutus* (p. 152)
30a Tuft of antenna single or double ; comb of about 25 spines ; pecten without wider-spaced spines...............................*pulchrithorax* (Vol. III, p. 429)
Antennal tuft of about 8 branches ; comb of 10–12 spines ; pecten with 2–3 wider-spaced spines distally.......................................*dentatus* (p. 149)

At the end of the first portion of section 37 delete "38" and read : "*albocephalus* (p. 140)". Delete section 38.

Delete section 42 and substitute :—

42. Antenna colourless ; subventral tuft of siphon placed much nearer to apex of siphon than to distal pecten-spine...*wigglesworthi* (p. 141, as atypical *abnormalis*)
Antenna infuscated for at least its distal half ; subventral tuft of siphon placed more basally, nearer to most distal pecten-spine than to apex of siphon...42a
42a. Antenna with proximal half not infuscated ; antennal tuft distinctly beyond middle..*alboventralis* (p. 142)
Antenna with less than proximal quarter pale ; antennal tuft at, or only slightly beyond, middle.......................*abnormalis kabwachensis* (Vol. III, p. 432)

For section 47 substitute :—

47. Pecten composed of 35–40 spines, none of which are markedly wider-spaced... *phyllolabis* (Vol. III, p. 430)
Pecten composed of less than 20 spines, of which at least one distal spine is much wider-spaced than the remainder...............................47a
47a. Subventral tuft of siphon with about 5 branches..............*hopkinsi* (p. 133)
This tuft with at most 3 branches..48

Key to Larvae of Culex (*Vol. I, pp.* 177–180).

In view of the variable siphonal index recorded by Edwards (p. 433) for *Culex argenteopunctatus kingi*, the statement that this species would run to *grahami* in my key is only true for some specimens, and it must be taken out earlier in the key.

For section 20 substitute :—

20. Spine on dorsal valve of siphon exceptionally long, conspicuously denticulate towards base.........................*argenteopunctatus kingi* (Vol. III, p. 432)

This spine short and inconspicuous, not denticulate..............................20a

⁁1 20a. Siphonal index ⁁2–15...*grahami* (p. 233)

Index at most 7...21

At end of second alternative of section 25, delete " *albiventris* (p. 186) " and read " 25a ". Insert new section as follows :—

25a. Head-seta A with about 6 branches ; pecten-spines with several basal denticles ; dorsal pair of gills much longer than saddle...............*albiventris* (p. 186)

Seta A with 3–4 branches ; pecten spines with only one basal denticle ; dorsal pair of gills about half length of saddle...............................*adersianus*

APPENDIX.

TWO NEW EAST AFRICAN CULICINE LARVAE.

By E. C. C. van Someren.

Section of Medical Entomology, Medical Research Laboratory, Nairobi.

Aëdes (Diceromyia) adersi, Edwards (fig. 1).

Head : Antenna sparsely spiculate, with shaft-hair of 2–3 simple branches at about a half. Seta A with from 8–14 sparsely plumose branches and about a half to two-thirds the length of C. Seta B with two simple branches about half the length

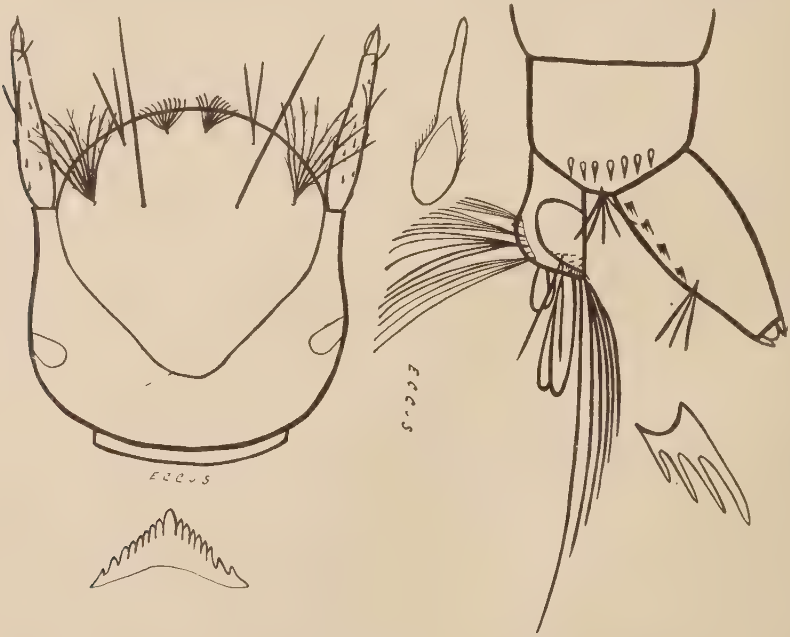

Fig. 1. Head and terminal segments of larva of *Aëdes* (*Diceromyia*) *adersi,* Edw.

of C, placed a little outside C and well up the head. C a simple seta, about half the length of the head and in a line with A ; in some specimens it was noted that C was sometimes forked at the apex. Seta *d* large, with 14–18 simple branches and about half the length of B. Mentum with one large tooth in the middle and 8 smaller teeth on each side, the last two being more widely spaced.

Abdomen : Setae on abdomen and thorax short and heavy, giving the larva a " prickly " appearance. Comb composed of 8–10 (usually 8) strong, sharp-pointed spines with a fringe of fine basal denticles. Siphonal index about 2 ; pecten spines from 4–6 in number (usually 6), broad and deeply indentated on the ventral side and sometimes also dorsally ; subventral tuft usually of 3 (sometimes 2) simple hairs, situated just beyond the pecten at a little more than half way along the siphon. Anal segment with an incomplete saddle which is heavily spiculated on the upper distal margin ; lower caudal seta single, upper with 5 branches, lateral tuft with 2–4 simple branches and about 1½ times the length of the saddle. Ventral brush damaged in most specimens, but seems to have 4 pairs of tufts of about 5 simple branches. Gills sausage-shaped, upper pair about twice the length of the saddle, lower pair about a third the length of the upper.

Breeding-places : Tree-holes and axil of banana leaf.

The larva is described from a pelt, the adult bred from which was identified by Dr. Edwards as *Aëdes adersi*, and a few whole larvae.

Culex (Neoculex) adersianus, Edwards.

The larva resembles that of *C.* (*N.*) *albiventris*, Edw., in all characters except that head-seta A has three to four plumose branches, the pecten spines have only one basal denticle, and the gills are broadly lanceolate and much shorter than in *albiventris*, the upper pair about half the length of the saddle and the lower pair about one-third the length of the upper.

Breeding-places : Tree-holes. It is almost certain that Aders' record of *albiventris* from holes in *Terminalia* trees in Zanzibar, quoted by Hopkins, refers to the present species.

Described from material obtained on the coast in Kenya, one pelt from Malindi, and about 40 whole larvae from Gede. The paedotypes of this species and of *Aëdes adersi* will be presented to the British Museum after the war.

NOTES ON CULICINE MOSQUITOS IN TANGANYIKA TERRITORY.

By W. Victor Harris, M.Sc. F.Z.S., F.R.E.S.*

In the course of entomological work undertaken as a part of the Yellow Fever precautionary measures carried out in Tanganyika Territory during 1941, further records of Culicine mosquitos were obtained. These are listed in Part I below together with the published records of Pomeroy (1920), Haworth (1924), Scott (1926), McHardy (1927, 1928 and 1930) and Edwards (1941). Certain published records have been omitted where they appear to be based on identifications inadequately confirmed, or where the locality given does not lie within the present boundaries of Tanganyika Territory. In the case of the more widely distributed species, citations of numerous authors are omitted.

Part II deals with the quantitative aspect of the *Stegomyia* population, based on collections from domestic and tree-hole sources, and on the results obtained by the use of bamboo pots to attract egg-laying females of the "small container breeding" species.

Annotated List of the Culicines of Tanganyika Territory.

Megarhinus brevipalpis, Theo.

Widely distributed ; larvae predacious on the larvae of other mosquitos ; usually found in tree-holes, but recorded once in a tin.

Megarhinus lutescens, Theo.

Kilosa (Edwards).

Harpagomyia taeniarostris, Theo.

Dar-es-Salaam (Pomeroy). Breeds in leaf axils.

Uranotaenia mashonaensis, Theo.

Dar-es-Salaam, Kilosa (McHardy).

Uranotaenia balfouri, Theo.

Dar-es-Salaam (Edwards).

Uranotaenia fusca, Theo.

Morogoro, breeding in rock pools at Turiani waterfall.

Aëdomyia furfurea, End.

Dar-es-Salaam (McHardy), breeding in marshy land near harbour.

Ficalbia (*Mimomyia*) *mimomyiaformis*, Newst.

Dar-es-Salaam (McHardy).

Ficalbia (*Mimomyia*) *plumosa*, Theo.

Bukoba (McHardy).

Ficalbia (*Mimomyia*) *splendens*, Theo.

Itigi. Larvae found in a quarry used for water storage, associated with *Taeniorhynchus africanus* among water lettuce (*Pistia*).

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Taeniorhynchus (*Coquillettidia*) *aureus*, Edw.

Ifakara. Adults biting among reeds on banks of Kilombero River.

Taeniorhynchus (*Coquillettidia*) *aurites*, Theo.

Bukoba (McHardy). Adults taken in marshy area.

Taeniorhynchus (*Coquillettidia*) *fuscopennatus*, Theo.

Musoma, Mwanza, Bukoba. Adults were numerous in camp along the lake shore south of Bukoba town.

Taeniorhynchus (*Coquillettidia*) *metallicus*, Theo.

Mwanza (McHardy).

Taeniorhynchus (*Mansonioides*) *africanus*, Theo.

Dar-es-Salaam, Morogoro, Itigi, Bukoba, Ifakara, Rufiji delta. The larvae are found in swamps and river backwaters, usually in association with water lettuce (*Pistia*). At Itigi, they were found in old quarries used as water reservoirs, among *Pistia*, together with *Ficalbia splendens* and *Anopheles squamosus*. Adults were obtained in houses half a mile away. Also numerous along the Kagera river in Bukoba.

Taeniorhynchus (*Mansonioides*) *uniformis*, Theo.

Dar-es-Salaam, Musoma, Bukoba, Malagarasi. Many adults were taken on a train shortly after arriving at Malagarasi station. Common also on the lake shore at Bukoba. There are records of *Taeniorhynchus* from a number of other localities, *e.g.*, Rufiji delta and Lake Rukwa, the species being undetermined.

Aëdes (*Mucidus*) *scatophagoides*, Theo.

Dar-es-Salaam. The larva is predacious on other mosquito larvae living in small pools. McHardy gives the following as its prey :—*Anopheles gambiae, Aëdes albocephalus, Culex decens.*

Aëdes (*Finlaya*) *fulgens*, Edw.

Dar-es-Salaam, Tanga, Korogwe, Mombo, Moshi. Breeds in tree-holes.

Aëdes (*Stegomyia*) *aegypti*, L.

Distributed throughout Tanganyika. There appears to be no reason why its absence from any populated area is other than a seasonal climatic effect. Larvae are found in small collections of water not heavily contaminated by vegetable matter. Tree-holes and rock holes are the natural breeding places of *A. aegypti*, but it has taken advantage of man-made or domestic water containers more efficiently than any other mosquito and can be found in water pots, flower vases, roof gutters, discarded tins and old iron, coconut shells, etc. It does not breed to a practical degree in puddles, borrow-pits, pools or earth drains unless metal or wood is present, and it is most uncommon in green plants such as bananas or pineapples. Owing to its ability to complete its life-cycle indoors, it can continue to develop in our urban areas independently of the general climate.

Aëdes (*Stegomyia*) *africanus*, Theo.

Bukoba. One record of larvae from a tin in the compound of an Indian house. Adults common as day biters in dense evergreen scrub below cliffs near the lake shore, associated with *A. apicoargenteus*, *A. minutus* and *Eretmapodites* sp.

Aëdes (*Stegomyia*) *apicoargenteus*, Theo.

Bukoba. Larvae from rock pools by the lake shore, tree-holes, water pots and discarded tins ; adults numerous in evergreen bush (see *A. africanus*), vigorous biters.

Aëdes (*Stegomyia*) *calceatus*, Edw.

Originally described from material collected by Haworth at Lindi; this *Stegomyia* has not been recorded here a second time.

Aëdes (*Stegomyia*) *de-boeri*, Edw.

Mombo, Moshi and Arusha (Lloyd), breeding in tree-holes.

Aëdes (*Stegomyia*) *luteocephalus*, Newst.

Mwanza. Larvae from numerous tree-holes and in one case a discarded tin. This record extends eastwards the range of a typical West African species.

Aëdes (*Stegomyia*) *metallicus*, Edw.

Widely distributed from the coast to Moshi and Mwanza. The larvae occur in tree-holes as a general rule, but on occasion they have been found in domestic water pots and coconut shells.

Aëdes (*Stegomyia*) *soleatus*, Edw.

Lindi, Dar-es-Salaam, and at points between Tanga and Moshi. The larvae are found in tree-holes and bamboo stumps.

Aëdes (*Stegomyia*) *simpsoni*, Theo.

Generally distributed. It rarely breeds in domestic sources. Larvae are usually found in the leaf axils of non-woody plants such as banana, pineapple, *Colocasia*, *Dracaena*, etc., and much less commonly in tree-holes. The females are greatly attracted towards bamboo pots containing water and used for obtaining data on egg laying. This species is more widely distributed and more numerous than is indicated by the usual house and tree-hole searches.

Aëdes (*Stegomyia*) *vittatus*, Big.

Widely distributed from the coast to Bukoba. Larvae are usually found in rock pools, but some have been taken in tree-holes and also in a pool in the road. Records of this species occurring in domestic water jars are usually from localities where rock pools are a source of drinking water. In Mwanza, where it is abundant, *A. vittatus* has been found in discarded tins on waste ground between houses. In Bukoba it is less common and its place is taken by *A. apicoargenteus*.

Aëdes (*Aëdimorphus*) *albocephalus*, Theo.

Lindi, Dar-es-Salaam, Tanga, Mombo, Korogwe, Muhesa. Larvae found in marshy pools in creeks and drains.

Aëdes (*Aëdimorphus*) *argenteopunctatus*, Theo.

Two adults captured on a passenger train travelling up the Central Railway. According to Hopkins (1936) this species breeds in pools among grass.

Aëdes (*Aëdimorphus*) *durbanensis*, Theo.

Dar-es-Salaam (McHardy), Morogoro. Adults taken in the rest house at Turiani.

Aëdes (*Aëdimorphus*) *fowleri*, d'Emmerez de Charmoy.

Morogoro. Reared from bamboo pots exposed in the township but more common about one thousand feet higher up the mountain among scattered native huts. Lembeni, near Moshi; larvae found in a hoof print in a dry river-bed (Lloyd).

Aëdes (*Aëdimorphus*) *haworthi*, Edw.

Tanga, tree-holes; Dar-es-Salaam, cement tank (McHardy); Morogoro, fairly numerous in bamboo traps, one record from a roadside borrow-pit; Arusha.

Aëdes (*Aëdimorphus*) *lamborni*, Edw.

Amani. Larvae in rock pools in river (McHardy).

Aëdes (*Aëdimorphus*) *leucarthrius*, Speiser.

Mt. Meru (Edwards).

Aëdes (*Aëdimorphus*) *minutus*, Theo.

Bukoba. Adults fairly numerous and biting in evergreen thicket in township. McHardy records it from marshy ground at Tanga.

Aëdes (*Banksinella*) *albicosta*, Edw.

Dar-es-Salaam, adults in houses ; Mombo (McHardy), one larva from a pool.

Aëdes (*Banksinella*) *albothorax*, Theo.

Dar-es-Salaam (Pomeroy).

Aëdes (*Banksinella*) *lineatopennis*, Ludl.

Mombo, Dar-es-Salaam, Bukoba. Larvae are found in marshy pools. In Bukoba larvae were associated with *Culex* sp. in a large rice field in the township. Adults were captured on a passenger train west of Tabora on the Central railway.

Aëdes (*Diceromyia*) *adersi*, Edw.

Dar-es-Salaam, Tanga, Lindi. The larvae are found in tree-holes, usually associated with *A. metallicus*.

Aëdes (*Diceromyia*) *fascipalpis*, Edw.

Tanga, reared from larvae in tree-holes. Also recorded from Lindi (Haworth) and Iringa district (Edwards).

Aëdes (*Diceromyia*) *furcifer*, Edw.

Muhesa (Lloyd), reared from larvae in tree-holes.

Aëdes (*Diceromyia*) *taylori*, Edw.

Tanga, Moshi, Arusha, Dar-es-Salaam, closely associated with *adersi*, in tree-holes.

Aëdes (*Dunnius*) *natalensis*, Edw.

Morogoro, Korogwe, Muhesa, Moshi, Arusha. Breeds in tree-holes.

Aëdes (*Skusea*) *pembaensis*, Theo.

Lindi, Dar-es-Salaam, Tanga. The larvae develop in crab-holes above normal tide level where the salinity of the water is reduced by fresh water seepage. The adults are fierce biters.

Eretmapodites chrysogaster, Graham.

Amani, Mombo (McHardy), Bukoba. The Bukoba specimens were taken in evergreen thicket, biting man. Owing to difficulties of identification in the absence of males, a number of records of *Eretmapodites* cannot be included. The distribution of the genus in Tanganyika is thus wider than these notes would suggest.

Eretmapodites intermedius, Edw.

Dar-es-Salaam (Edwards).

Eretmapodites quinquevittatus, Theo.

Dar-es-Salaam, Lindi, Bukoba, Tanga. Larvae generally found in snail shells.

Eretmapodites subsimplicipes, Edw.

Dar-es-Salaam, Lindi. Larvae in tree-holes and discarded coconut shells.

Culex (*Lutzia*) *tigripes*, Grandpré & Charmoy.

Generally distributed. The larvae are predacious on other mosquito larvae, especially the small container breeders, and are found in ditches, pools, water tanks, discarded tins, etc., and snail shells, but not usually in tree-holes where its place is taken by *Megarhinus*.

Culex (*Mochthogenes*) *inconspicuosus*, Theo.

Dar-es-Salaam, Tanga, Mombo. Breeding in water-holes, seepage pools, marshes and river backwaters (McHardy).

Culex (*Culiciomyia*) *nebulosus* var *pseudocinereus*, Theo.

Common at the coast, where it breeds in small collections of rain-water in pools, tree-holes, water barrels, discarded tins, etc. Also recorded at Mombo and Amani (McHardy).

Culex (*Neoculex*) *horridus*, Edw.

Morogoro, reared from bamboo traps hung in the shade of large tree; Itigi, reared from a deep stone-lined well in association with *C. fatigans*; Tanga; Muhesa; Dar-es-Salaam; Lindi.

Culex (*Neoculex*) *rubinotus*, Theo.

Bukoba. Adults caught in camp on the lake shore.

Culex (*Culex*) *annulioris*, Theo.

Dar-es-Salaam, from Tanga to Mombo, Amani (McHardy). Breeding in pools and streams where the flow is slow and among vegetation.

Culex (*Culex*) *antennatus*, Beck.

Dar-es-Salaam (Pomeroy), Mwanza (McHardy). Adults taken in camp on the lake shore at Bukoba were doubtfully placed in this species by Edwards.

Culex (*Culex*) *bitaeniorhynchus*, Giles.

Widely distributed from Dar-es-Salaam to Mwanza and Tanga to Arusha, breeding in clean water of streams, drains, dams, etc., where vegetation is present.

Culex (*Culex*) *decens*, Theo.

Widely distributed from the coast to Lake Victoria breeding in the margins of ditches, drains, swamps and streams, usually among long grass.

Culex (*Culex*) *duttoni*, Theo.

General from the coast to the lakes. The larvae are commonly found in streams, pools, and lake shore swamps. It has been found during the dry season in cement and iron water tanks at Shinyanga, and in rock pools green with rotting vegetation in a river near Morogoro.

Culex (*Culex*) *ethiopicus*, Edw.

Dar-es-Salaam (Edwards).

Culex (*Culex*) *fatigans*, Wied.

Widely distributed throughout the Territory and breeding in all manner of small collections of water, including cesspits, cattle watering holes, wells, domestic containers and swamp pools. The adults are particularly obvious in houses of the large towns during the dry season, when control measures against *Aëdes* and *Anopheles* are most effective.

Culex (*Culex*) *guiarti*, Blanch.

Bukoba (McHardy).

Culex (*Culex*) *invidiosus*, Theo.

Dar-es-Salaam (Edwards).

Culex (*Culex*) *perfuscus*, Edw.

Dar-es-Salaam (Scott,).

Culex (*Culex*) *pipiens*, L.

Bukoba, Mwanza, in swampy ground on the Lake Shore ; Morogoro, Mombo, in marshy areas. McHardy records it from tins and jars at Mombo. It is no doubt as widely distributed as *C. fatigans* though less domestic in habit.

Culex (*Culex*) *poicilipes*, Theo.

Mkomasi (McHardy), on the Tanga railway, a single specimen reared from a river pool.

Culex (*Culex*) *simpsoni*, Theo.

Widely distributed in river pools, seepage pools, and slow moving water containing vegetation. Also found in rock pools in a river near Morogoro, and, in association with *Anopheles gambiae*, in a pool below domestic water tank at Shinyanga.

Culex (*Culex*) *sitiens*, Wied.

Dar-es-Salaam, Lindi. Breeding in cesspits.

Culex (*Culex*) *thalassius*, Theo.

Dar-es-Salaam, from salt water on the foreshore. Not a common species.

Culex (*Culex*) *theileri*, Theo.

Kondoa Irangi (Edwards).

Culex (*Culex*) *trifilatus*, Edw.

Amani (McHardy), Morogoro. Larvae in rock pool in river ; numerous larvae in bamboo pots at 3,000 ft. on mountain side.

Culex (*Culex*) *trifoliatus*, Edw.

Dar-es-Salaam, Tanga.

Culex (*Culex*) *tritaeniorhynchus*, Giles.

Dar-es-Salaam. McHardy records larvae breeding at a single plantation on the borders of the township, presumably in stagnant pools. Other records are of the adults only.

Culex (*Culex*) *univittatus*, Theo.

Generally distributed on the coast, and at Moshi, Kilosa, Kondoa Irangi, Mwanza and Bukoba, in clear water such as slow running streams, seepage pools, and rain water pools.

Culex (*Culex*) *watti*, Edw.

Dar-es-Salaam (Edwards).

Distribution.

In considering the geographical distribution of mosquitos in Tanganyika, the zonation described by Edwards (1941) must be amplified to include the northern part of Bukoba in the " Uganda Savannah District " in order to account for the presence in our list of such species as *Aëdes africanus* and *A. apicoargenteus*.

The Tanganyika section of the " Central African Highlands " is mainly a low plateau with a distinctly long dry season, and characterised by the absence rather than by the presence of typical species.

Excluding such salt water breeding mosquitos as *Aëdes* (*Skusea*) *pembaensis* and *Culex thalassius*, the " Lowlands " appear to fall into two sub-divisions, a narrow strip within reach of the light coastal showers where *A. albocephalus* and *A. adersi* are found, and the remainder of the coastal plain.

Little is known of the mosquito fauna of the mountain forests of Tanganyika.

The Culicines of major importance in regard to yellow fever, *Aëdes aegypti, A. simpsoni* and *A. vittatus* are widely distributed throughout the Territory.

NOTES ON AËDES POPULATION.

Collections from Natural Sources.

During the 10 months February to November 1941, bi-weekly collections of larvae other than *Anopheles* and *Culex* were received from the Medical Officer of Health, Dar-es-Salaam. These were random samples of the collections obtained by the house and tree searchers on *Stegomyia* control. The number of collections received from domestic sources was 986, being approximately 17 per cent. of those found, while 69 were received from tree-holes, representing 30 per cent. of the total. Most of the identifications were made from adult mosquitos reared from the larvae. The number of collections in which each species were found is tabulated below :—

TABLE I.

Dar-es-Salaam—Domestic Sources.

Number of collections examined	986
Number with *Aëdes* (*Stegomyia*) *aegypti* ...	975 (99%)
,, ,, *Aëdes* (*Stegomyia*) *simpsoni* ...	6
,, ,, *Aëdes* (*Stegomyia*) *metallicus* ...	6
,, ,, *Aëdes* (*Diceromyia*) *adersi* ...	2
,, ,, *Eretmapodites quinquevittatus* ...	3

The sources of *Aëdes aegypti* were varied ; they included earthenware water pots, iron drums, wooden barrels, buckets, soakage pits, gulley traps, flower vases, lavatory pans, machinery, motor car parts including mudguards, cylinder blocks and tyres, and hand holes in inspection chamber covers.

Aëdes simpsoni came from a broken flower pot, an iron tank, a flower vase, and three times from old tins.

Aëdes metallicus occured twice in water pots, once each in an ice machine, a tin, an iron tank, and a coconut shell.

Aëdes adersi was found in a water pot and an iron tank.

Eretmapodites quinquevittatus occurred in a tin, an iron tank and a bottle. It is more commonly found in discarded shells of the larger land snails.

For the first six months of the year, *Aëdes* spp. represented 84 per cent. of all collections found in domestic sources, *Culex* spp. 15 per cent. and *Anopheles* spp. 1 per cent. Thus more than four out of every five cases of mosquito breeding in houses, compounds, etc., referred to *Aëdes aegypti*.

TABLE II.

Dar-es-Salaam—Tree-holes.

Number of collections examined	69
Number with *Aëdes* (*Stegomyia*) *aegypti*	53 (77%)
,, ,, *Aëdes* (*Stegomyia*) *simpsoni*	15 (22%)
,, ,, *Aëdes* (*Stegomyia*) *metallicus* ...	23 (33%)
,, ,, *Aëdes* (*Diceromyia*) *adersi*	4 (6%)
,, ,, *Aëdes* (*Finlaya*) *fulgens*	1
,, ,, *Eretmapodites quinquevittatus* ...	1

The occupation of a tree-hole by two or even three species of mosquito larvae at the same time is a frequent occurrence. The trees involved included *Mangifera indica* (Mango), *Cocos nucifera* (coconut), *Casuarina equisetifolia, Albizzia lebbek* and *Terminalia catappa* (Indian almond). Larvae were found in only 3 per cent. of trees inspected. Of the collections obtained, 3 per cent. were *Culex* spp., and the remainder *Aëdes* spp. Broadly speaking two trees in a hundred produced *A. aegypti,* one in a hundred *A. metallicus,* and less than one in a hundred *A. simpsoni.*

Throughout this period there was no indication in either habitat of any seasonal variation in the relative abundance of the commoner species of mosquitos. The decline in numbers with the onset of the dry season and as a result of *Stegomyia* control measures was general.

Experiments with Bamboo Pots.

It is suggested that under the conditions prevailing in most townships in Tanganyika the "*Aëdes* index" does not give a complete picture of the relative mosquito situation because, as shown above, it relates almost exclusively to *A. aegypti* and does not take into account this and other probably equally important species breeding in non-domestic sources. Experiments were therefore carried out to find whether bamboo pots containing water to attract egg-laying female mosquitos could be used to obtain comparative figures more indicative of the whole *Stegomyia* population, and particularly if such a system could be extended to rural areas. Bamboo pots were used by Dunn (1927) in Nigeria in studies on seasonal variation, site preferences and distance from human habitations in relation to the breeding of *Aëdes aegypti.*

After preliminary trials, the following system was adopted. Local bamboos with an internal diameter between two and three inches were cut immediately below the node and then again from seven to nine inches above the node, making a container capable of holding on an average 12 fl. oz. of water to within two inches of the rim. A loop of string passed through two holes near the rim to form a handle and a serial number painted on the side completed the outfit. Before being placed in service, all pots were allowed to stand in the open, filled with stream water, for at least one week, otherwise the initial record was generally low and unreliable. Pots were exposed in batches of 25 for a period of five days in each locality. Each batch was then collected and, after topping up with water, allowed to stand for three days in a mosquito-proof insectary, or under a mosquito net. After this time, the water was emptied out of each bamboo in turn into a glass dish and any larvae present transferred to large test-tubes, numbered similarly to the pots. Larvae of *Megarhinus* were discarded as soon as they were detected. On emergence of the adults, the species of *Aëdes* was recorded, otherwise in most cases only the genus was noted. No record was kept of the number of individual mosquitos emerging from each pot, but only the number of pots in each batch of 25 from which each species was obtained.

Records were obtained during the period May to September from three areas in Morogoro township at approximately weekly intervals. During this period many other batches of pots were exposed in the township for various purposes, and the frequency with which each species was recorded is shown below. The total number of bamboo pots exposed was 3,400.

TABLE III.

Species and Occurrence of each in Morogoro Township.

Aëdes (*Stegomyia*) *aegypti*	924
Aëdes (*Stegomyia*) *simpsoni*	772
Aëdes (*Stegomyia*) *metallicus*	9
Aëdes (*Aëdimorphus*) *haworthi*	15
Aëdes (*Dunnius*) *natalensis*	5
Culex spp.	21

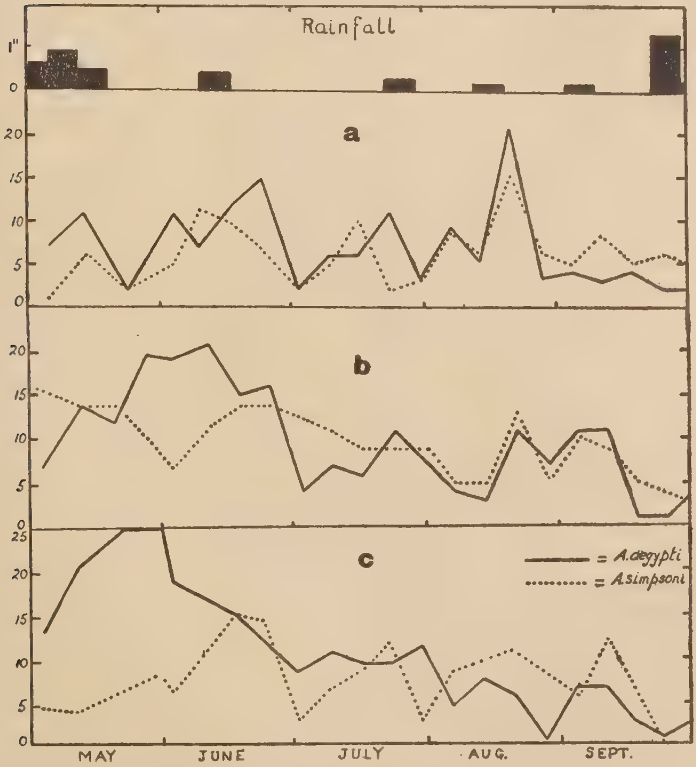

Fig. 1. Fluctuations in populations of *Aëdes aegypti* and *A. simpsoni*, as indicated by egg-laying in bamboo pots exposed for 5 days in batches of 25, at weekly intervals, in three localities of Morogoro township. May–September 1941. Weekly rainfall totals shown above.

All the records of *Culex* spp. were obtained during the month of May. The results obtained each week from the three fixed stations are shown graphically in figure 1. The period covered the last of the heavy rains, and the dry winter months when only occasional showers occur. The three stations chosen were :—

A. The vicinity of the laboratory, pots hung in an avenue of *Cedrela* trees adjacent to farm buildings and three African quarters ; no other dwellings within half a mile.

B. Boma street, better class native houses densely shaded by an avenue of tall mango trees, pots hung under eaves of houses and on compound fences at a constant height of five to six feet.

C. West street, parallel to Boma street, some 200 yards away, not shaded except for a few coconut palms ; pots suspended under eaves and on fences.

TABLE IV.

Monthly Averages for Fixed Stations, Morogoro.

(25 pots, 5 days).

Station		May	June	July	Aug.	Sept.
A	*aegypti*	21	16	10	5	4
	simpsoni	6	13	8	10	5
B	*aegypti*	13	18	7	6	6
	simpsoni	16	12	8	7	6
C	*aegypti*	7	11	6	9	3
	simpsoni	4	8	4	9	5
Mean	*aegypti*	14	15	8	7	4
	simpsoni	9	11	7	9	5

On two occasions only were all 25 pots found to contain larvae of one species (*A. aegypti*). The anticipated sharp fall in numbers of mosquitos after the rains is best shown in stations A and B. There are fewer opportunities for breeding in tree-holes at C, where results were, on the whole, surprisingly uniform. The *Aëdes* index for the township as a whole was 2·0 in April and nil in August. Thus in towns more heavily infested with *Stegomyia* mosquitos, the bamboo pots might require a shorter exposure than five days. *Aëdes aegypti* ceased to be evident indoors as a nuisance when the bamboo pot index fell below 10/25. *Aëdes simpsoni* was hardly ever found indoors.

In order to see if elevation had any significance on egg-laying, batches of bamboo pots were suspended from the leaves of young coconut palms, roughly 20 feet above ground, and from those of mature palms, roughly 60 feet high, while corresponding groups of pots were hung at the usual height around houses below.

TABLE V.

Effect of Elevation on Egg-laying.

	aegypti			*simpsoni*		
	13.v.	21.v.	28.v.	13.v.	21.v.	28.v.
60 ft.	4	6	2	15	19	22
20 ft.	12	—	—	11	—	—
Ground...	14	12	16	14	14	16

These results would suggest that female *A. simpsoni* will seek out suitable places for egg-laying at 60 ft. above ground while those of *A. aegypti* prefer lower levels.

With regard to *Aëdes* infestation in areas far removed from dwellings, pots were exposed on the Morogoro aerodrome at weekly intervals from May to July. Twenty-five pots were hung on the wind indicator and store in the middle of the aerodrome, at a distance of 0·7 miles from the last of a row of native huts leading to the town. Large trees and water-courses are in no direction closer than the nearest hut, and the whole aerodrome is well exposed to winds.

TABLE VI.

Egg-laying in Bamboo Pots on Aerodrome, Morogoro.

(25 pots, 5 days).

Date	No. with *aegypti*	No. with *simpsoni*
27.v.	0	3
3.vi.	2	4
9.vi.	5	7
17.vi.	4	5
24.vi.	2	5
1.vii.	3	3
24.vii.	1	3
Average	2·4	4·3
Average in township over same period	9·5	8·3

While the results are consistently low in comparison with the township, sufficient numbers of both *aegypti* and *simpsoni* appear to be in movement during the dry season to produce an infestation if suitable breeding places were permitted to exist on the aerodrome.

In the Mtibwa forest, 60 miles north of Morogoro, a single series of observations was made during August. In the centre of the evergreen rain forest, 200 yards from a small village on the main road, no larvae were obtained. On the southern border of the forest, where it begins to open into drier savannah country, although there was no habitation within one mile, four pots contained *A. aegypti* larvae and two *A. simpsoni*.

Two series of observations were carried out at fortnightly intervals in a densely populated rural area of the mountain slopes above Morogoro in open cultivated country well watered but with few trees. The species obtained are tabulated with their frequencies.

TABLE VII.

Species obtained in Bamboo Traps near scattered Huts on Mountain Slopes.

Aëdes (Stegomyia) aegypti	50
Aëdes (Stegomyia) simpsoni	10
Aëdes (Stegomyia) vittatus	4
Aëdes (Dunnius) natalensis	1
Aëdes (Aëdimorphus) fowleri	—
Uranotaenia sp.	—
Culex spp.	—
Anopheles sp. (each a single larva)	2

Owing to an unfortunate mistake, some of the records of *A. fowleri* and all of *Uranotaenia* were lost when the pots were swamped by *Culex* spp. during late August and early September. *A. fowleri* was common during July and August. For brevity, the records of the two stations are amalgamated and expressed as monthly averages on a basis of 25 pots.

TABLE VIII.

Monthly Average of Results from two Series of Traps exposed fortnightly on Mountain Slopes.

	aegypti	*simpsoni*	*Culex*
May	0	5	0
June	3	2	0
July	9	0	0
August	15	0	5
September	7	0	11

This shows a far greater variation in the commoner species of *Aëdes*, both in relation to one another and seasonally, than is exhibited in any of the urban records. The factors causing this are not known.

Summary.

The examination of mosquito larvae collected by house searchers on *Stegomyia* control measures in Dar-es-Salaam, the largest town in Tanganyika, shows that *Aëdes aegypti* is definitely the predominant domestic breeder there. The other species of the genus *Aëdes* encountered are listed with their frequencies.

Similarly the examination of larvae found in tree-holes in Dar-es-Salaam shows that *Aëdes aegypti*, *A. simpsoni* and *A. metallicus* are regularly encountered.

A system of obtaining an index of the population density of both *A. aegypti* and *A. simpsoni*, unconnected with the actual process of *Stegomyia* control measures, is described. This would be applicable to smaller towns, rural districts, and towns in high rainfall areas where *A. aegypti* is not the only danger as a yellow fever vector, and where extra-domestic breeding is important. The system is based on the exposure of a fixed number of bamboo pots containing water for a constant period of days, to attract egg-laying female mosquitos. Species of mosquitos and their frequencies obtained in a series of trials are given.

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I wish to express my appreciation of the assistance afforded me by Dr. Botha De Meillon in identifying specimens, by Mrs. E. C. C. van Someren and Mr. G. H. E. Hopkins in supplying much useful reference material, and by Mr. H. M. Lloyd, who carried out the initial survey of the villages along the Tanga-Arusha railway.

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SIMPLE TESTS FOR ESTIMATING THE SUITABILITY OF MINERAL OILS AS MOSQUITO LARVICIDES.

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In practice it is seldom found that any one of the numerous grades of oil prepared from crude petroleum is a satisfactory mosquito larvicide. The final product is almost invariably blended from several constituents. Each of the constituents may confer beneficial properties on the larvicide directly, or it may serve to correct undesirable features possessed by the other ingredients.

Even under world conditions which might be regarded as normal compared with those prevailing to-day, difficulties have confronted those who wished to select or blend a larvicide. There was firstly, in the remoter parts of the world, a lack of any specialised chemical apparatus ; secondly, the lack of a complete minimum performance specification by which to judge laboratory blends ; and thirdly, the difficulty arising from the fact that the specifications supplied for commercial grades of oil do not include data on many properties of the oil which are important to the malariologist but unimportant to the usual consumer.

This paper represents an endeavour to overcome the three difficulties outlined above. It provides a minimum performance specification for a larvicide and describes a series of simple tests which may be applied (*a*) to a commercially blended larvicide in order to establish whether this meets the requirements of the specification, and (*b*) to the individual ingredients (*e.g.*, kerosines, Diesel oils or fuel oils) so that, in each case, the one with the most desirable combination of properties may be selected for incorporation in the final blend.

The Specification.

> A mineral oil larvicide acts by coming into contact with the larvae and entering the tracheae through the spiracles. An adequately oiled larva never reaches maturity. The desirable properties of a malariol are those which help to make contact with, and penetration into, the larva most likely.

The commonly accepted description of an efficient mineral oil larvicide runs somewhat as follows :—a cheap mixture of oils of suitable viscosity which when sprayed on to the water surface spreads well into a thin uniform, persistent, stable film which is toxic to the larvae and pupae of the mosquito and to vegetation on and around the water surface.

These properties may be more exactly embodied in the following specification, which is accompanied by notes on the significance of the tests for the present purpose.

1. *Specific Gravity.*

> Specific gravity at 15°C./4°C. should not exceed 0·950.

The only importance of this test is to ensure that the specific gravity of the larvicide does not approach too closely to that of the water (1 approx.) on which it must form a surface film. In practice this difficulty seldom arises, since most of the hydrocarbon constituents of mineral oil have specific gravities less than unity ; however, with certain highly aromatic mixtures this is not the case and it is well to have the point in mind.

2. *Volatility.*

When a distillation test is carried out in accordance with American Society for Testing Materials Method No. D158/38 or the Institute of Petroleum Method No. G.O.3, 1935, not more than 5 per cent. of the volume of the sample taken should distil over at 200°C.

(The 5 per cent. vol. limit referred to above is somewhat arbitrarily fixed, and slight departures from it may sometimes be indicated if experience shows that the larvicide is satisfactory in other respects.)

From the point of view of penetration and toxicity, it is desirable that a larvicide should contain an appreciable percentage of volatile ingredients such as kerosine. However in the field these volatile constituents are readily lost by evaporation so that the film becomes too viscous and thereby loses much of the toxicity and penetrating properties originally conferred upon it by these ingredients. The volatile material is provided by the range of constituents of various boiling points in the kerosine, and the distillation test serves to ensure that the larvicide does not contain too high a percentage of the ingredients in the more volatile end of this range.

The volatility test is thus intended to give an indication of the change in composition which a larvicide is likely to undergo as a result of evaporation when exposed in a thin film in practice. For the comparison of two larvicides it is quite a useful test, but its application to field conditions is in many ways artificial. However, direct measurements of loss by evaporation are very difficult to reproduce in the laboratory and the distillation test is applied as a convenient routine alternative.

Even the distillation test, however, involves specialised apparatus and rigid adherence to the American Society for Testing Materials Method or the Institute of Petroleum Method instructions, which makes it impracticable for the present purpose. Instead one may adopt the procedure outlined under Test Procedure.

3. *Viscosity.*

The kinematic viscosity should not exceed 10·0 centistokes at 70°F., which is equivalent to 52 sec. Redwood I—1·83 degrees Engler both at 70°F.

(See note under Volatility Specification.)

The main importance of the viscosity specification is concerned with the passage of the oil through the spiracles and up the main tracheal trunks of the larvae. If the oil is too viscous, penetration will be inhibited or retarded. As has been shown (Murray, 1936 ; Watson, 1941) oiling of the tracheae is of primary importance in killing the larvae : adequately oiled larvae seldom or never reach maturity.

4. *Spreading Pressure.*

The spreading pressure, determined as described, should not be below 16 dynes per cm.

This test is of fundamental importance since the spreading pressure of an oil determines whether it will cover the treated water surface evenly, spreading out against any naturally occurring contaminating film, or whether it will remain in thick localised patches.

The spreading pressure of an oil may be accurately determined by the use of the Adam-Langmuir Trough (Adam, 1938) the technique being modified as described by Murray, 1939, but it is unusual to make this determination in routine testing. The procedure normally employed consists in comparing the larvicide with solutions made up to known spreading pressures as determined on the Adam-Langmuir apparatus. Mixtures of highly refined petroleum oils with dodecyl alcohol are sometimes employed for this purpose.

In the test described, castor oil is employed as a standard. It has been found that most fresh samples of pure medicinal castor oil have a spreading pressure of about 16 dynes/cm. Its ready availability is greatly in its favour as a standard for this test.

5. *Permanence of Film.*

When spread on the surface of water as described under the test procedure the film must remain uniform and unbroken for at least 2 hours (showing neither holes nor thick lens-like patches).

There is some difference of opinion concerning optimum persistence of the film on the treated water surface, since old films lose much of their efficiency and then merely interfere with the spreading of the new film. The loss of efficiency referred to is partly due to evaporation and the accompanying increase in viscosity. But other changes take place in the oil under the influence of light, etc. The exact nature of the changes is not fully understood.

However, certain mixtures are inherently unstable and in a period of minutes or hours, films formed from them either break up into thick lenses of oil separated by extremely thin areas or show the appearance of round holes of various sizes. It is important to examine the larvicide for these defects.

6. *Toxicity Test.*

When tested in accordance with the instructions given, at least 50 per cent. of the larvae must be killed when *Aëdes aegypti* (*Stegomyia fasciata*) is used as the test insect, or 90 per cent. when *Anopheles maculipennis* is used as the test insect.

The test to be carried out at 25°C. (77° F.).

Obviously this test is of first importance since the final criterion of the efficiency of a larvicide is its ability to kill the larvae. There is a considerable difference between the resistance of *Stegomyia* and *Culex* larvae on the one hand and Anopheline larvae on the other. In practice, it would obviously be wise to collect representatives of the species which has to be controlled, and to use these in the toxicity test.

Test Procedure.

In the following pages a description of the test procedure to be adopted under field conditions is given. No instructions are given for using the specialised instruments employed in the larger laboratories since it is assumed that printed instructions will always be available where the apparatus is at hand.

1. *Specific Gravity.*

A hydrometer of suitable range say from 1·000 down to 0·850 is very convenient if available—otherwise gently pipette a layer of oil about one-eighth of an inch thick on to the surface of water in a glass vessel. Unless the oil sinks immediately stir gently and then leave it for about 15 minutes. If at the end of that time the water is clear and the oil/water interphase sharp, the oil may be judged to be satisfactory.

Normally this test will only be performed on the ready product or on the proposed blend, when it is known that one of the ingredients has a specific gravity in excess of 1 as determined by it sinking when poured on to the top of water.

2. *Volatility Test.*

The following considerations make it possible to avoid the necessity for carrying out this test where the prescribed apparatus is not available :—

(i) when dealing with ready made commercial samples carry out all the other tests and if they are satisfactory, repeat the toxicity test, setting up the bowl and oiling it as described later, but only introducing the larvae after the film has been exposed under field conditions for six hours. There should be no appreciable change in toxicity.

(ii) when a blend is being prepared, the only ingredient likely to give rise to excessive volatility difficulties is the kerosine, the distillation range of which varies widely but is usually between 140° and 300°C. The percentage of kerosine should therefore be kept down to a minimum compatible with efficiency in other respects. A maximum of 10 per cent. volume in the blend will almost always meet the case. Additional information may be obtained on the matter by reference to the normal marketing specification under which the kerosine is sold, since this almost always includes information on distillation characteristics.

3. *Viscosity.*

In the laboratory one of the standard instruments for determining the viscosity of mineral oils would be used. A capillary tube type of viscometer for determination of kinematic viscosity or the Redwood, Saybolt or Engler viscometers for conventional viscosities.

These instruments may be dispensed with by the following procedure :—

Make up a mixture of 55 per cent. volume pure glycerine and 45 per cent. volume distilled water ; this mixture has a viscosity equal to the specified maximum at 70°F.

Take an ordinary 25 or 50 cc. pipette and ring the outlet tube with a piece of gummed paper about 2 inches below the bulb. Bring the glycerine/water mixture to 70°F. (21°C.) by cautiously warming it over a small flame or cooling if necessary. Draw this into the pipette, fix the pipette vertically in a clamp and take the time in seconds for the solution to flow out from the graduation mark down to the gummed paper ring. Repeat the test and take the average time. If possible choose a pipette with an outflow of 30–60 sec. Clean out the pipette, dry, and having brought the proposed larvicide to 70°F. (21°C.) run it through in the same way. The time taken should not exceed that for the glycerine/water mixture.

4. *Spreading Pressure.*

The spreading pressure is assessed as described by Murray (1938).

Fix a 6–8 in. diameter glass funnel in an upright position and connect the stem to a water supply by means of rubber tubing. The apparatus should be set up over a sink or some other provision made to collect the waste water. When the water supply is turned on, it fills the funnel and should be allowed to overflow for a short time until a completely clean surface is obtained. Then turn off the water and, by tilting the funnel slightly, bring the water surface to about one-eighth inch below the rim of the funnel. The apparatus is now ready for the first test.

Take a clean glass rod in each hand, dip one into castor oil, and the other into the sample to be tested and lower a drop from each rod on to the water surface more or less simultaneously. Observe the spreading of the oils by looking along the water surface horizontally. There are three possible results :—

(*a*) The castor oil spreads over the major part of the surface area—in this case the spreading pressure of the castor oil is greater than that of the larvicide, *i.e.*, the larvicide has a spreading pressure below 16 dynes/cm. and cannot be regarded as satisfactory.

(*b*) Both oils occupy an approximately equal area of the water surface, *i.e.*, the spreading pressures are both about equal at 16 dynes/cm.

(*c*) The larvicide occupies most of the surface, *i.e.*, it has a spreading pressure above 16 and may be regarded as satisfactory.

Whatever the conclusion, it is advisable to repeat the test. Sometimes better results are obtained by putting the drop of larvicide on to the water surface just before the castor oil and observing the change of the first drop after adding the second. If the larvicide is pushed back into a small area in the presence of castor oil, then it has a spreading pressure below that of the castor oil.

In carrying out this test it is very important to see that the funnel is completely clean, and between each test it must be thoroughly washed out by overflowing. The same considerations of cleanliness apply to all the glass rods and receptacles employed, since traces of impurities may have very considerable effects on the value of the spreading pressure.

This test may be applied to the ready larvicide and to any ingredients which it is proposed should be used in the composition of a larvicide. Besides comparing the ingredients against castor oil, they may be compared in exactly the same way against each other, in order that the one with the highest spreading pressure can be chosen if this is compatible with efficiency in other respects, *e.g.*, stability of the film and toxicity.

Further consideration is given to the question of making up blends in Appendix I.

5. *Permanence of Film.*

Take a china or enamel hand bowl about 30 cms. in diameter and thoroughly clean it with water (hot water may be used with advantage but avoid the use of soap).

Give the bowl a final rinse out and then fill it about three-quarters full with clean water ; be careful not to touch the inside of the bowl. Gently pipette about 0·5 ml. of the larvicide on to the water surface. If the oil does not spread evenly almost to the edge of the bowl, repeat the test, since the bowl was insufficiently washed.

Examine the oil film after two hours. Only if it is still uniform may it be regarded as satisfactory. The blend should not be accepted if holes or lenses form within this period.

This test is only applied to the finished larvicide and not to individual ingredients since it has been found that comparatively small changes in composition appreciably affect film stability. (See Murray, 1938, and Appendix I.)

6. *Toxicity Test.*

The importance of this test has already been indicated ; it is carried out as follows :—

Take an enamel or other suitable bowl and clean it as described under "Permanence of Film Test." Nearly fill the bowl with clean water, bringing the temperature to 25°C. In the bowl stand a bottle having a short neck about 1 in. in diameter. The bottom of the bottle should have been removed at such a level that the mouth of the neck is about 2 inches above the water surface. The bottle may be neatly cut by tying a piece of wool soaked in paraffin around it at the chosen level, igniting the paraffin and slowly turning the bottle in order to heat it up all round. When the bottle is hot, plunge it quickly into a bucket of cold water. The bottle should crack around the heated part. Wash the bottle carefully.

When the bottle prepared as described is standing in the bowl, put the larvicide on to the water surrounding the neck. The bowl should be covered with a complete film right up to the edge ; if this is not the case, the apparatus was insufficiently washed. For a bowl 30 cms. in diameter, use 0·5 ml. larvicide, *i.e.* enough to form a film 10 μ ($\mu = \frac{1}{1000}$ mm.) thick.

Transfer 10 fully grown larvae from the culture to a beaker of clean water so as to free them from debris which would contaminate the water in the test bowl, and then to a convenient specimen tube. Use a bulb teat-pipette for this purpose. Now transfer the larvae to the oiled bowl, introducing them through the neck of the bottle which should be held away from the bottom but not removed from the bowl. When the larvae are all outside the bottle, replace it on the bottom of the bowl.

By following the above technique it is possible to get the larvae under the evenly spread film without any possibility of accidentally oiling them.

Allow the larvae to remain under the oil film for 30 minutes and then remove them to a clean beaker by running the pipette through the neck of the bottle. Remove those at the bottom first and if necessary any larvae sticking in the surface film may be caused to sink by touching with a glass rod. Set the beaker aside (preferably at about 25°C.) and observe the larvae after 24 hours. If the larvae show no sign of swimming movement after gently touching with a glass rod, they may be considered dead.

This test besides being applied to the finished larvicide can with advantage be applied to the more volatile basic ingredients, *e.g.*, kerosine or Diesel oil, so that the sample in each class with the highest toxicity can be chosen, provided that this is compatible with other requirements.

APPENDIX I.

Blending Larvicides.

It may be helpful to conclude with a short note on the type of procedure which should be followed when blending larvicides and to give some indication of the ways in which defects may be corrected.

For this purpose larvicide ingredients may be divided into three categories (refer to Appendix II for a general outline of the properties of the petroleum products concerned) :—

1. Kerosine—*i.e.* the ordinary domestic paraffin oil used in lamps and stoves. In larvicides it reduces viscosity, and increases penetration and toxicity, but excess is to be avoided on account of comparatively high volatility.
2. Diesel Oil or Gas Oil—the fuels used in compression ignition engines, *e.g.*, Diesel as the name implies. Often form the main body of larvicides since they are not too viscous to penetrate fairly readily, and at the same time may be toxic and possessed of good spreading powers.
3. Fuel Oils—either light or heavy which are burnt in furnaces of various types. In larvicides they are usually included to increase film stability and spreading pressure and to reduce the cost of the mixture.

When several examples of each class are available, test each separately, the kerosine, Diesel and gas oil, for toxicity and spreading pressure, and the fuel oils for spreading pressure. Compare the samples one against another and against castor oil in the Spreading Pressure Test. Make sure that either the Diesel oil, gas oil or fuel oil chosen has a spreading pressure above that of castor oil. Unless this is the case it will be necessary either to procure material with a higher spreading pressure or to add to the blend the prescribed quantity of spreading agents supplied by commercial firms for this purpose.

Having carried out these tests select the kerosine and Diesel oil so as to obtain a good combination of toxicity and spreading pressure or, if the spreading pressure of the fuel is really high, one may concentrate on toxicity. From the selected ingredients, make up the following trial blend in a 100 c.c measuring cylinder: 10 per cent. vol. kerosine, 70 per cent. vol. Diesel oil, 20 per cent. vol. fuel oil.

Mix thoroughly and determine whether the viscosity is below the specified maximum. If it is, proceed with the other tests; if it is not, make up another blend containing less fuel oil. Test the chosen blend for spreading pressure, permanence of film and toxicity in that order.

If the spreading pressure is too low, try increasing the percentage of Diesel oil, or fuel oil (whichever has the higher spreading pressure), but do not exceed the maximum viscosity, or if this fails, it would be well to consider adding the prescribed amount (usually under 1 per cent.) of a specially prepared spreading agent.

If the film is unstable, make up a new blend substituting the second choice kerosine and/or Diesel oil for all or part of the quantities previously employed. Try also increasing the fuel oil content up to the maximum permitted by the viscosity specification or alternatively a different fuel oil with the original kerosine/Diesel oil mixture.

The factors which determine film stability are somewhat complex (Murray, 1938) and depend on the relative proportion of aromatic and paraffinic ingredients in the mixture (a 50/50 mixture tends to be unstable) and upon the relative volatility of these two constituents. When all the aromatic constituents are more volatile than the paraffinic constituents this also leads to instability.

Certain oils, usually residues left after distillation (*e.g.*, fuel oils) may contain complex ingredients which act as film stabilisers, so that it is usually advisable to include a certain percentage of these heavy residues in the larvicide.

If the toxicity is low, this may be due either to failure of the larvicide to penetrate into the larval tracheae or actual low toxicity of the oil which would make it slow acting. The remedy lies in (*a*) choosing ingredients which are more toxic, but perhaps less satisfactory in other respects and reaching a compromise blend, (*b*) reducing the viscosity by increasing the kerosine up to a maximum of 15 per cent. or reducing the fuel oil content, (*c*) there is the final possibility of adding up to 1 per cent. of cresylic acid to the blend, but this is to be avoided if possible since although it helps spreading initially, its final result is detrimental.

Finally, it is important to realise that a good larvicide often represents a compromise between the various desirable properties. As has already been stated, it is often best to choose ingredients with all round average good properties, especially for the initial experimental blends, and then to correct any defects by adding an oil strongly possessed of the deficient quality to the next blend prepared.

APPENDIX II.

Petroleum Products.

For those quite unfamiliar with petroleum technology, the following notes may prove useful.

The usual commercial classification of petroleum products is based on volatility and viscosity, and there are broadly speaking two kinds: products obtained as distillates from crude petroleum and products obtained as distillation residues. The following table gives typical values for the properties of ingredients likely to be included in larvicides :—

Usual name	Appearance	Type	Specific gravity at 15°/4°C.	Average Redwood I viscosity at 100°F. in seconds	Boiling range °C.
Kerosine... ...	Colourless or pale yellow	Distillate	0·820	Less than 30	140–300°C.
Gas oil	Yellow to light brown	Distillate	0·830	35–45	From 160 app. to 350+*
Diesel oil ...	Light brown to dark red brown	Distillate	0·840	40–100	
Fuel oil—					
Light	Black—viscous	Residue+ Distillate	From about 0·890 to 1·000+	From about 200 (light) to 6,000 (heavy)	Above 300°C.*
Heavy... ...	Black—very viscous	Residue			

* The upper limit of the boiling range cannot be determined owing to decomposition.

Within the grading by viscosity and distillation a considerable variation in chemical properties is possible, depending upon the nature of the crude oil from which the product was obtained. This variation in chemical composition is of first importance as far as larvicides are concerned and broadly speaking three types may be recognised.

1. The *paraffinous type*, consisting mainly of the hydrocarbons of the saturated chemically unreactive paraffin series. Oils in this class tend to have poor toxicity and low spreading pressures.

2. The *aromatic type*, containing an appreciable percentage of aromatic hydrocarbons which are chemically more reactive and much more toxic.

3. The *unsaturated or cracked type*, containing an appreciable percentage of olefinic hydrocarbons either derived naturally from the crude or produced during refinement. Members of this class are chemically active and tend to have good spreading pressures and toxicities. They are characterised by a strong and unpleasant odour.

In the Petroleum Company's storage depots the types may be roughly separated or mixed, depending largely upon the source of supplies and the demands of the local markets. It is therefore important for any one who is developing a larvicide to obtain some guarantee that the composition of the material in the tanks when the bulk order is drawn is essentially similar to that of the experimental sample, otherwise the bulk quantity of larvicide may fall short of the experimental sample in efficiency. It is very important to remember that two oils may be apparently identical and in fact interchangeable as far as all the ordinary commercial specifications are concerned, and yet one may be effective in a larvicide and the other more or less useless. For this reason too it is advisable to draw and test fresh samples, and if necessary to modify the formula of the larvicide on each occasion when a new order is placed. It is a wise precaution to ask for the samples to be supplied from full storage tanks and to test them at the very first opportunity, and finally to order the bulk quantity with a minimum delay as such an arrangement reduces the possibility of a disappointment resulting from the changed composition of the material in the storage tanks.

My thanks are due to Dr. V. B. Wigglesworth for reading through the paper generally, and to Mr. W. Pohl of the Shell group of oil companies for examining the section dealing more specifically with petroleum products. The work was done during the tenure of a research grant from the Medical Research Council.

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SOME NOTES ON THE INTEGUMENT OF INSECTS IN RELATION TO THE ENTRY OF CONTACT INSECTICIDES.

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The object of this paper is to consider certain structural and physiological features of the insect cuticle and their bearing upon the entry of insecticides, particularly extracts of pyrethrum in oil.

The cuticle consists of three layers: (i) An inner, elastic, moist, fibrous layer of chitin and protein (the endocuticle); (ii) An outer, hard, inextensible layer of variable thickness in which an amber or brown material (sclerotin) is incorporated with the chitin (the exocuticle); (iii) A very thin outermost layer consisting of sclerotin alone without chitin (the epicuticle). There is evidence that sclerotin consists mainly of "tanned protein" (Pryor, 1940). The water content of the exocuticular type of cuticle which is impregnated with it, is much less than that of the white elastic endocuticular type (Fraenkel & Rudall, 1940). Associated with the epicuticle is lipoid material of varying properties which is thought to be important in rendering the cuticle impermeable to water (Kühnelt, 1928; Hurst, 1942). Pryor (1940) has pointed out how very readily sclerotin is wetted by oils; it is possible therefore that such lipoid may sometimes extend far into the exocuticle. And the fact that the permeability of the endocuticle, as well as that of the epicuticle, is increased by oils, suggests that lipoids occur in this layer also (Hurst, 1942).

Numerous cytoplasmic filaments extend from the epidermal cells through the endocuticle and, for at least some time after its formation, through the exocuticle, but do not penetrate the epicuticle (Wigglesworth, 1933; Klinger, 1936). The ducts of dermal glands pass right through the cuticle. These are probably more abundant than is generally supposed. Finally there are the sockets of the setae, around which the cuticle is much thinner than elsewhere. All these elements must be taken into account in considering the passage of substances through the cuticle.

The Effect of Oil in contact with the Cuticle.

If a small insect such as a flea or a louse is held beneath a coverslip and immersed in a refined petroleum oil (medicinal liquid paraffin) or in olive oil, minute droplets of water can be seen with the microscope to exude from the surface of the cuticle. These appear within about half an hour. At the end of two hours the droplets are conspicuous everywhere. On the tarsal claws of the louse (fig. 1, A) and on the stout bristles of the flea (fig. 1, B) the drops are so large that they clearly cannot have been expressed solely from the substance of the cuticle but must have passed through from the tissue fluid. If a lighter oil, such as kerosene or xylol, is used the droplets appear within five minutes.

The mechanism by which these droplets of water are liberated is uncertain. Their formation is not dependent on compression of the insect, for they appear also if an isolated limb is immersed in oil. Possibly traces of long chain polar substances dissolved from the cuticle by the oil crowd into the water surface and so cause the water to be drawn out in the form of droplets. (Sometimes the larger drops have smaller ones budding from their surface.) But similar droplets are produced if a drop of water on a waxed slide is covered with a very thin film of paraffin wax and immersed in liquid paraffin. Whatever the mechanism of their formation, they provide evidence of the readiness with which oil applied to the insect comes into contact with its watery substance.

When the experiments were repeated with *Cimex*, limbs of *Rhodnius*, or small larvae of *Tenebrio*, a great difference was found between insects that had moulted only a few days and insects a month or so old. Water droplets pass far more readily through the cuticle of the young insects.

These experiments prove that oils dissolve or permeate the lipoid film on the surface of the cuticle and so reach the water in its deeper layers. This can be demonstrated in another way. It was shown by Hurst (1940) that if a larva of *Calliphora* is immersed in a mixture of equal parts of kerosene and ethyl alcohol, there is a violent swirling of fluid in contact with the cuticle, the larva swells by the rapid entry of alcohol, and the kerosene and alcohol in the mixture separate. More recent extensive work by Hurst (1941, 1942) has proved that besides the simple factor of relative solubility in oil and water (Wigglesworth, 1941), there are other factors responsible for the " induced penetration " of the alcohol. Thus permeability is influenced also by adsorption factors and by changes in the physico-chemical structure of the cuticle framework. The nature and degree of these changes vary with different cuticles and permeating media (Hurst, 1941, 1942). But whatever the mechanism of their penetration, mixtures of this kind, which separate in the presence of water, will serve as indicators that contact with water has been established. Examples of such mixtures are equal parts of white spirit* or of kerosene and ethyl alcohol, of a heavier oil (KB30*) and propyl alcohol, and of a heavier white oil (P31*) or medicinal liquid paraffin and butyl alcohol.

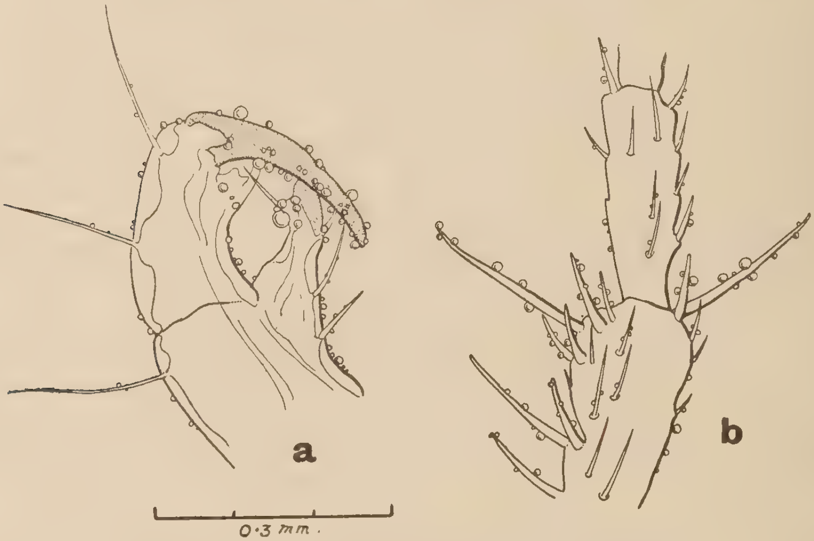

Fig. 1. A, Tarsus and claw of louse, *Pediculus*, after immersion in liquid paraffin for several hours. B, part of leg of flea, *Xenopsylla*, similarly treated.

Immersed in a mixture of equal parts kerosene and ethyl alcohol, the louse (*Pediculus*) instantly begins to effervesce violently all over the abdomen, at the bases and joints of the legs, the neck, around the mouth and at the joints and apex of the antennae. Droplets emerge from all these parts, swell up as the alcohol separates into them and whirl away into the surrounding fluid. Later they emerge, though less violently, from the leg segments and to a small extent from the claws. They do not seem to come from the segments of the antennae.

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* The characters of these particular oils are given later (p. 208).

In equal parts of medicinal liquid paraffin and butyl alcohol effervescence begins much more slowly. There is some individual variation ; but in a typical experiment the droplets began to stream out at the following times after immersion (20°C.): sides of abdomen, 25 secs. ; base of legs, 35 secs. ; neck and round mouth, 45 secs. ; base of claws and all leg joints, 55 secs. ; base of antenna, 1 min. 15 secs. ; first antennal joint, 2 min. 15 secs. ; apex of antenna, 3 min. 5 secs. ; other antennal joints, 5 min. At the end of 6 minutes, effervescence was proceeding everywhere except on the claws and the segments of the legs and antennae.

In a mixture of an intermediate paraffin (KB30) and propyl alcohol similar results were obtained, but effervescence usually began rather sooner.

These experiments show that there is a striking difference in the ease with which these different oil mixtures get into contact with the water in the integument. Such differences may be due to differences in the solubility of the lipoid constituents of the epicuticle in the various oils or to the physico-chemical structure of the cuticle being such that the light oils enter more readily than the heavy.

This question has been tested by immersing the louse for 1–2 hours in petroleum ether, in order to dissolve away the lipoid layer, before placing it in the oil and alcohol mixture. Insects so treated, allowed to dry thoroughly, and then immersed in the mixture of medicinal liquid paraffin and butyl alcohol begin to effervesce instantly (in less than 2 seconds) along the sides of the abdomen, the bases and joints of the legs, the neck and around the mouth. Whereas the untreated insects required immersion for 25 seconds to 5 minutes before they showed such effects.

This suggests that the rate of solution of the lipoid is probably one factor which determines the rate of entry of the oil. But there are certain parts of the cuticle (the claws, the segments of the legs and antennae and the sides of the head) which fail to show effervescence in the heavy oil mixture, even after extraction in petroleum ether. This probably means that there are also structural differences in the cuticle which prevent or retard the entry of the heavy oils.

The Entry of Pyrethrum Extract in Different Oils.

The foregoing experiments show that light oils pass into the cuticle more readily than heavy oils. Such differences might be expected to influence the rate of entry of insecticides, such as pyrethrum, in solution in the oils. This question has been studied by applying a constant concentration of pyrethrins to a standard area of cuticle on the back of an insect and comparing the rate of action in different solvents.

Methods.—The insect used was the blood-sucking bug, *Rhodnius prolixus*. Either 5th stage nymphs, 24 to 48 hours after a full meal of blood, or adults were employed. Rings were cut from a standard piece of glass tubing (5·75 mm. external, 4·0 mm. internal diameter), ground level on one side, and on the other side ground to fit the back of the insect—saddle-shaped for the rounded backs of the nymphs, flat for the adults. The rings were 3 mm. deep. They were sealed to the back, always to the same segments, with a cement composed of equal parts flexile collodion B.P. (celloidin in alcohol and ether with the addition of a little resin) and copal varnish in alcohol. After drying for 24 hours, this cement is quite resistant to oils and water. A thin layer of washed silver sand was placed on the cuticle enclosed by the ring ; about 20 c.mm. of the solution to be tested introduced ; and the capsule closed above by putting on a coverslip 5 mm. square and sealing the edges with paraffin wax.

The test solutions were prepared as follows : 0·1 cc. of an alcoholic extract of pyrethrum containing 2 per cent. of total pyrethrins was evaporated to dryness in the dark at about 35°C. in a flat bottomed capsule one inch in diameter. The residue was then taken up in 0·1 c.c. of the solvent to be tested. The final solution may well have contained slightly less than 2 per cent. of pyrethrins ; but parallel experiments with several solvents were always carried out, so that comparative results were obtained.

When *Rhodnius* is treated with pyrethrum, it develops symptoms in a regular sequence: (i) The hind legs become uncoordinated; (ii) all the legs uncoordinated but the insect can still walk; (iii) the insect unable to walk. Meanwhile the proboscis, which is normally folded back beneath the head, is extended progressively, 10°, 30°, 45°, 90° and finally, in the completely paralysed insect, 180°. Any of these stages may be taken as the end point in judging the rate of entry of the poison; but in most experiments the time required to reach the final stage of complete paralysis with fully extended proboscis has been used. All the experiments were done at 25° C.

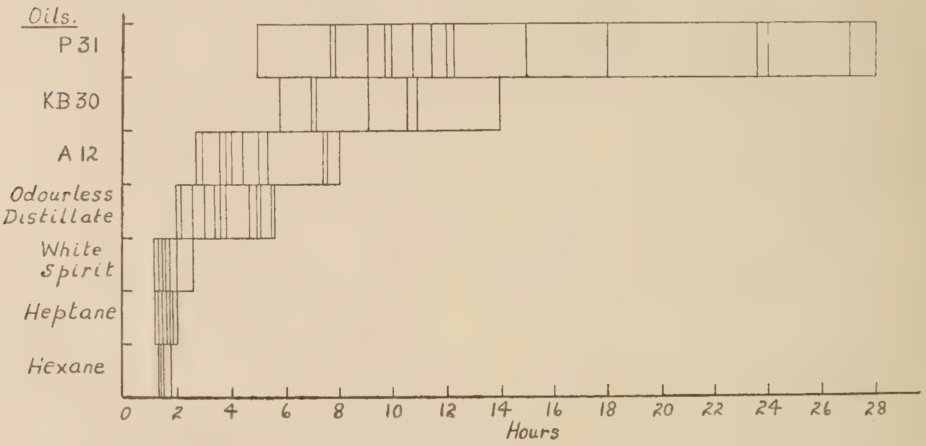

Fig. 2. Chart showing the time in hours required for complete paralysis of 5th stage nymphs of *Rhodnius* exposed to 2 per cent. of total pyrethrins in different oils. The vertical lines represent single insects.

Results.—Fig. 2 summarises the results obtained on 5th stage nymphs with petroleum oils.* The rate of entry of the pyrethrins, as indicated by the time required for complete paralysis, becomes progressively slower with the heavier oils; ranging from 1½ to 2 hours with hexane and heptane to a median value of about 12 hours with the white oil P31.

The rate of entry in vegetable oils is slower still. Two per cent. pyrethrins in olive oil caused paralysis in one insect in 36 hours; in others in 2 or 3 days; at least half the insects showed no effect at all after 4 days. Similar results were obtained with castor oil and sesame oil.

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* The following are some of the characters of the petroleum oils used:—

Oil	Boiling range	Viscosity (Redwood I at 20°C.)	Unsulphonatable residue
White spirit	150–190°C.	—	—
Odourless distillate ...	198–257°C.	32 sec.	99%
A12	265–365°C.	44 sec.	85–90%
KB30...	310–390°C.	95 sec.	91%
P31	320–	141 sec.	99%

Robinson (1942) using the muscular contractions of the immobile larva of the tick *Ornithodorus* as the index of penetration, likewise found more rapid entry of pyrethrum from P31 than from vegetable oils (cottonseed, linseed, castor). Working with other insects, notably blowfly larvae, Hurst (1942) has found that the relative influence of different solvents on the permeability of the cuticle may be even greater than in *Rhodnius*.

In the preceding section it was shown by immersion of the louse in mixtures of oils and alcohols that heavy oils penetrate to the watery layers of the cuticle more slowly than light oils, but that this difference disappears if the cuticle is first treated with petroleum ether. Similarly it has been found that previous extraction of the cuticle with petroleum ether accelerates the entry of pyrethrum dissolved in a heavy oil.

For example, six 5th stage nymphs of *Rhodnius* had capsules secured to the back as described. The capsules were filled with petroleum ether, which was continuously removed and replenished during half an hour. The cuticle was then allowed to dry thoroughly in air, and 2 per cent. pyrethrins in the medium white oil (KB30) applied. They began to show paralysis in 1½ to 2 hours and were completely paralysed in an average of 5 hours. In six controls without previous treatment with petroleum ether, paralysis was beginning in 6 hours and was still not complete after 8 hours.

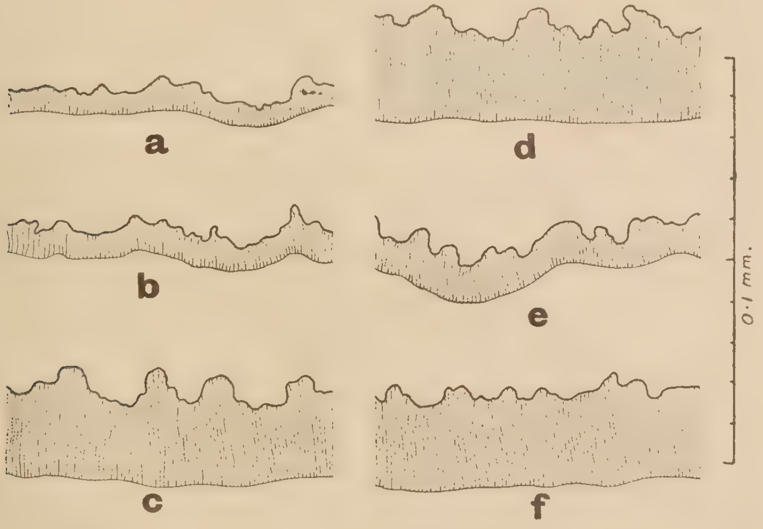

Fig. 3. Sections through the abdominal cuticle of 5th stage nymphs of *Rhodnius*. A, given 32 mg. of blood in the 4th stage ; B, given 44 mg. of blood ; C, given 140 mg. of blood ; D, given 142 mg. of blood ; E, given about 70 mg. of blood ; F, given about 70 mg. of blood in the 4th stage and then given a succession of small meals in the 5th stage.

Individual Variation in the Rate of Entry of Pyrethrum.

The insects used in comparative experiments were always of the same age, from the same batches, and reared together in the same jars. Yet, as can be seen in fig. 2, the individual variation is very great. The chief cause of this variation was traced to the thickness of the cuticle. In one very variable series treated with 2 per cent. pyrethrins in P31 with the addition of 5 per cent. oleic acid (p. 212), sections of the cuticle were cut. One insect which was completely paralysed in 1½ hours had a cuticle about 8–9 μ thick ; one paralysed in 2 hours about 10 μ thick ; in 8 hours about 18μ thick ; in 8–9 hours about 20 μ thick.

The only possible cause for such differences in thickness seemed to be the size of the previous meal (*Rhodnius* takes only a single large meal of blood in each stage). This was tested by taking a number of 4th stage nymphs of uniform size and of an average weight of 17 mg., allowing them to ingest varying amounts of blood and weighing them again. They were then allowed to moult and the rate of entry of pyrethrins was tested in the 5th stage nymphs when these had been kept for about 3 weeks after moulting. The larger the meal received in the 4th stage the greater is the quantity of undigested blood carried over into the 5th stage.

Fig. 3 shows sections through the cuticle of some of the insects. Fig. 3 A and B were from insects given 32 and 44 mg. of blood in the 4th stage. Treated with 2 per cent. pyrethrins in P31 containing 5 per cent. of oleic acid these were both fully paralysed in 2¼ hours. Fig. 3 C and D were from insects given 140 and 142 mg. of blood. Treated in the same way they showed complete paralysis in 10½ and 11½ hours.

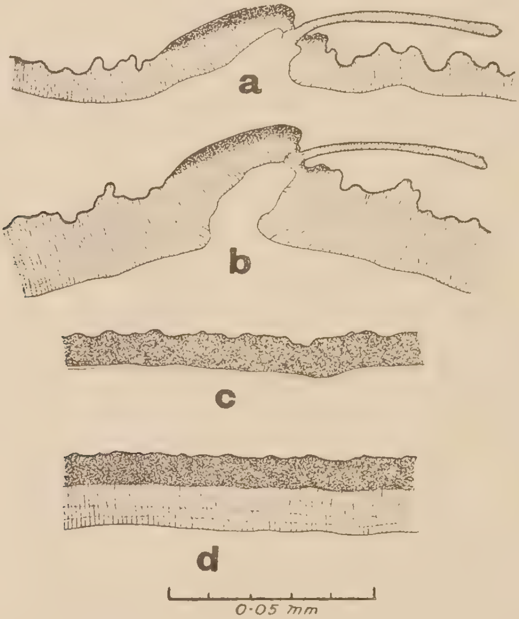

Fig. 4. A, section through plaque and adjacent region of cuticle of 5th stage nymph of *Rhodnius* with abdomen fully distended by blocking the anus; B, the same in normal nymph; C, section through abdominal cuticle of adult 24 hours after moulting; D, the same 1 month after moulting.

It is well known that a great part of the endocuticle is laid down after moulting. Its formation is likely to be influenced by the nutrition of the insect, and this may in consequence affect the permeability of the cuticle to pyrethrins. A series of 5th stage nymphs which had been given small meals of blood in the 4th stage (ranging from 59 to 78 mg.) were divided into two lots. One lot was given very small feeds* at weekly intervals for a month. They were then given normal meals and treated with 2 per cent. pyrethrins in P31. The unfed series showed complete paralysis after the following times (hours): 3¾, 4¼, 4¼, 4¾, 5¼, 5¼. The insects that had been given repeated feeds showed paralysis in 12½, 14, 14, 15, 15 hours.

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* Large meals which distend the abdomen initiate moulting in *Rhodnius*, but small meals can be given repeatedly without this effect (Wigglesworth, 1934).

Fig. 3 E, F shows sections of the cuticle from these two groups. The epicuticle shows no detectable changes. An exocuticle is present in the abdominal cuticle of *Rhodnius* nymphs only below the plaques which surround the bristles (Wigglesworth, 1933). The only visible difference is in the increased thickness of the endocuticle in the fed insects. From this it follows that it is probably the endocuticle of the nymphs which offers the chief resistance to the entry of pyrethrum.

The next question is the part played by the pore canals and the sockets of the bristles. The abdominal cuticle of the nymph is covered with plaques bearing bristles. There are about 450 in the area enclosed by the capsule. If the anus is blocked with paraffin wax immediately after a full meal, so that the abdomen remains excessively stretched, this number is reduced to about 300. At the same time the cuticle is much reduced in thickness.

Fifth-stage nymphs in this stretched condition treated with 2 per cent. pyrethrins in P31 showed complete paralysis in an average of 45 minutes ; normal insects from the same batch in 9 hours. As a result of the stretching the number of sockets in the exposed area is reduced. These cannot therefore be the sole points of entry. In the fully distended insect the epicuticle is partially unfolded, not stretched (Wigglesworth, 1933) ; this will not favour the passage of the insecticide. The greatly increased rate of entry in the distended insect must therefore be attributed to the reduced thickness of the endocuticle.

Fig. 4 A, B shows sections of the cuticle in these stretched and unstretched insects. It will be noted that the thickness of the endocuticle in the stretched condition (fig. 4, A) is approximately the same as in the unstretched nymphs which had been given very small feeds in the 4th stage (fig. 3, A, B). And yet the speed of action of the pyrethrum is far greater in the stretched insects (45 minutes as against 2¼ hours).

The most probable reason for the stretched cuticle being more permeable than the unstretched cuticle of equal thickness is to be found in the effect of stretching on the pore canals. Sections of the unfixed cuticle cut with the freezing microtome and mounted without staining in De Faure's medium, show that in the stretched condition, as in the unfed insect, the pore canals run a more or less vertical course from the cells to the epicuticle. They are therefore much shorter in the stretched insects. Since their contents are presumably unchanged in volume, their cross section must be increased. (They appear larger in the sections but it is impossible to make any true estimate of the change.) If the pore canals form the chief pathway for the insecticide through the cuticle, it may well be that entry is favoured by the increased diameter produced by stretching. Whether stretching has a similar effect on the ducts of the dermal glands is uncertain.

Passage of Pyrethrum through the Cuticle of Adult Rhodnius.

The abdominal cuticle of adult *Rhodnius* has an exocuticle, laid down before moulting, present everywhere except at the intersegmental membranes and other points of flexion, and an endocuticle laid down during the days that follow moulting (Wigglesworth, 1933, Wigglesworth & Gillett, 1936).

Fig. 4, C, D, shows sections of the cuticle 24 hours and 1 month after moulting. Six adults 24 hours after moulting, treated with 2 per cent. pyrethrins in P31, showed complete paralysis in 4–7½ hours (median value 5¼ hours). Six adults fed at intervals for 1 month after moulting required 8¼–12 hours (median value 10¼ hours).

In the adult *Rhodnius* there are very few bristles and sockets in the central region of the abdomen enclosed by the capsule. Ducts of dermal glands are fairly numerous. Their possible importance in the entry of the insecticide will be considered in the next section.

Histological Demonstration of the Entry of Oils through the Cuticle.

In order to see whether the oils themselves pass through the cuticle into the cells below, and with the object of demonstrating the chief points of entry, various oil mixtures, with or without pyrethrum, have been left in the capsules from 6 to 24 hours. The tergites of the abdomen have then been removed and mounted whole. They were fixed in Altmann's fluid, followed by Black Sudan B in 70 per cent. alcohol if the oil used did not blacken osmic acid, and mounted in syrup. Comparisons with different oils have been made on the same insect (i) by dividing the capsule with a partition of stout celluloid cemented to the glass, (ii) by placing two capsules one behind the other on the back. The second method is applicable to 5th stage nymphs stretched by sealing the anus after feeding.

Experiments with 5th stage nymphs.—When the white oil P31 was applied for 24 hours to normal 5th stage nymphs 24–48 hours after feeding, no oil droplets could be detected in the cells of the general epidermis or beneath the sockets of the bristles. Nor was olive oil absorbed under these conditions.

On the other hand, with oleic acid in the capsule, abundant droplets were everywhere visible. These were largest and most numerous below the plaques around the bristles, where the cells are more crowded together. But the general epidermal cells were also full of oil droplets (fig. 5, A).

Similarly, if 5 per cent. of oleic acid was added to P31 or to olive oil, droplets were plentiful, although not so conspicuous as with oleic acid alone (fig. 5, B).

If the cuticle is excessively stretched by occluding the anus immediately after feeding, some absorption of olive oil and of the pure paraffin P31 takes place, and these appear in the form of tiny droplets in the cells (fig. 5, C). This absorption is greatly increased by the addition of 5 per cent. oleic acid (fig. 5, D).

In order to see whether other surface active substances of a non-fatty nature (and therefore not themselves demonstrable by the fat-staining methods employed) would induce absorption of refined paraffin or of olive oil, 5 per cent. of "Aerosol OT"* (a proprietary wetting agent, the dioctyl ester of sodium sulphosuccinate) was added to them. This leads to an increased absorption of P31 and of olive oil, though the effect is not so striking as that of oleic acid.

From these experiments it appears that in the nymph of *Rhodnius* the oil enters the cuticle chiefly around the bristles and plaques; if very little is taken up, it may be almost limited to these sites. Dermal glands are concentrated here (Wigglesworth, 1933); but the oil droplets appeared to be in the epidermal cells and not in the substance of the glands. Whether absorption in such cases is through the margins of the socket itself or through the thin cuticle below the plaque is uncertain; but where widespread absorption is taking place (fig. 5, B, D), there is no doubt that it occurs through the general cuticle.

In no preparation has it been possible to detect oil in the substance of the cuticle. It must pass through in droplets or particles beyond the resolving power of the microscope. There is very much less absorption along the intersegmental membranes, which are completely smoothed out in the nymph after feeding. The cuticle here has the same thickness and structure as elsewhere; the only detectable difference is in the paler and softer character of the epicuticle.

The effect of thickness of cuticle on the visible uptake of oils was clearly seen in the experiment (p. 210) in which nymphs that had been given small feeds in the 4th stage were compared with those given large feeds. When mounted after exposure for 24 hours to 2 per cent. pyrethrins in P31 plus 5 per cent. oleic acid, far more absorption had taken place in the insects with the thin cuticle (fig. 5, E, F, *cf.* fig. 3, A, C).

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* Obtained through the courtesy of Mr. A. Shepperdson, Imperial Chemical Industries Ltd.

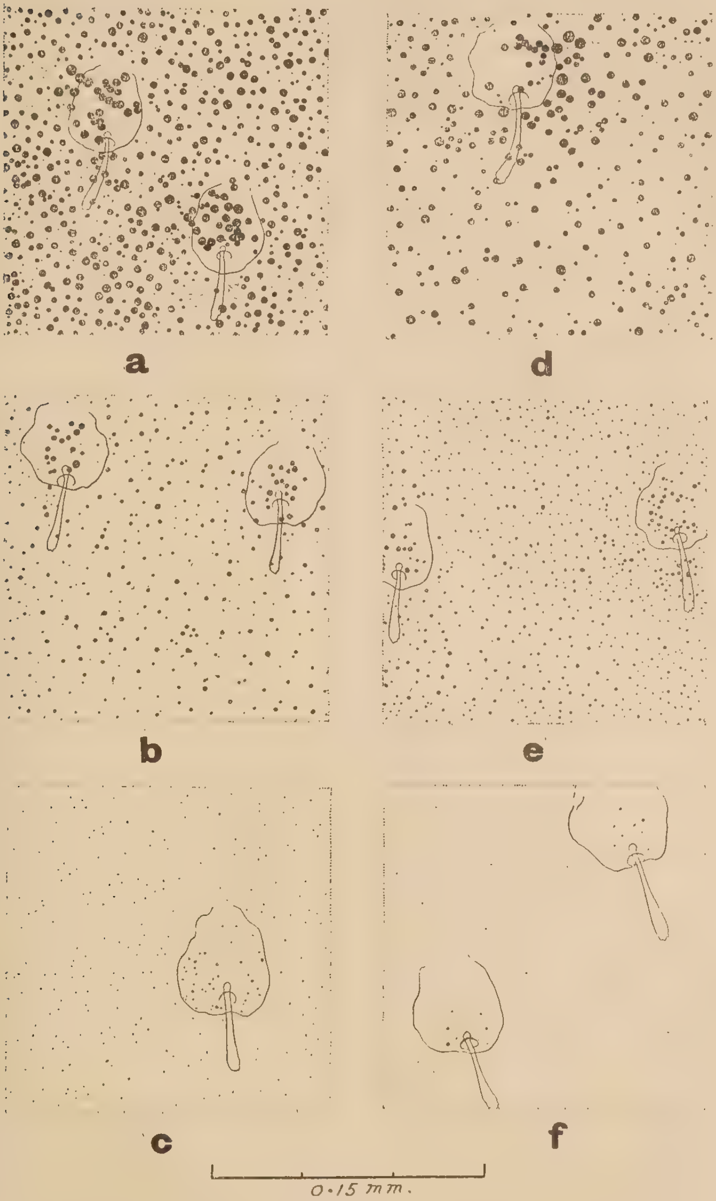

Fig. 5. Surface views of abdominal cuticle of 5th stage nymphs of *Rhodnius* showing oil droplets in the epidermis. A, exposed to oleic acid for 24 hours; B, exposed to P31 containing 5 per cent. oleic acid for 24 hours; C, stretched cuticle exposed to P31 for 24 hours; D, stretched cuticle exposed to P31 plus 5 per cent. oleic acid for 24 hours; E, thin cuticle (same insect as in fig. 3, A) exposed to P31 plus 5 per cent. oleic acid for 24 hours; F, thick cuticle (same insect as in fig. 3, C) exposed to P31 plus 5 per cent. oleic acid for 24 hours.

Experiments with adults.—If P31 plus 5 per cent. oleic acid is applied to the abdominal cuticle of the adult *Rhodnius* within one day of moulting, and left for 24 hours, numerous small droplets of oil appear in all the epidermal cells in the area enclosed by the glass ring (fig. 6, A). There is no increase around the sockets of the scanty bristles. The drops are present also and are in fact most numerous in the epidermal glands, but these do not stand out conspicuously from the rest of the epidermis on that account.

In the adult treated in the same way 4 days after moulting, oil droplets are almost absent from the general epidermal cells, and there are none below the bristles and sockets. Droplets are very plentiful, however, in the dermal glands (fig. 6, B) which

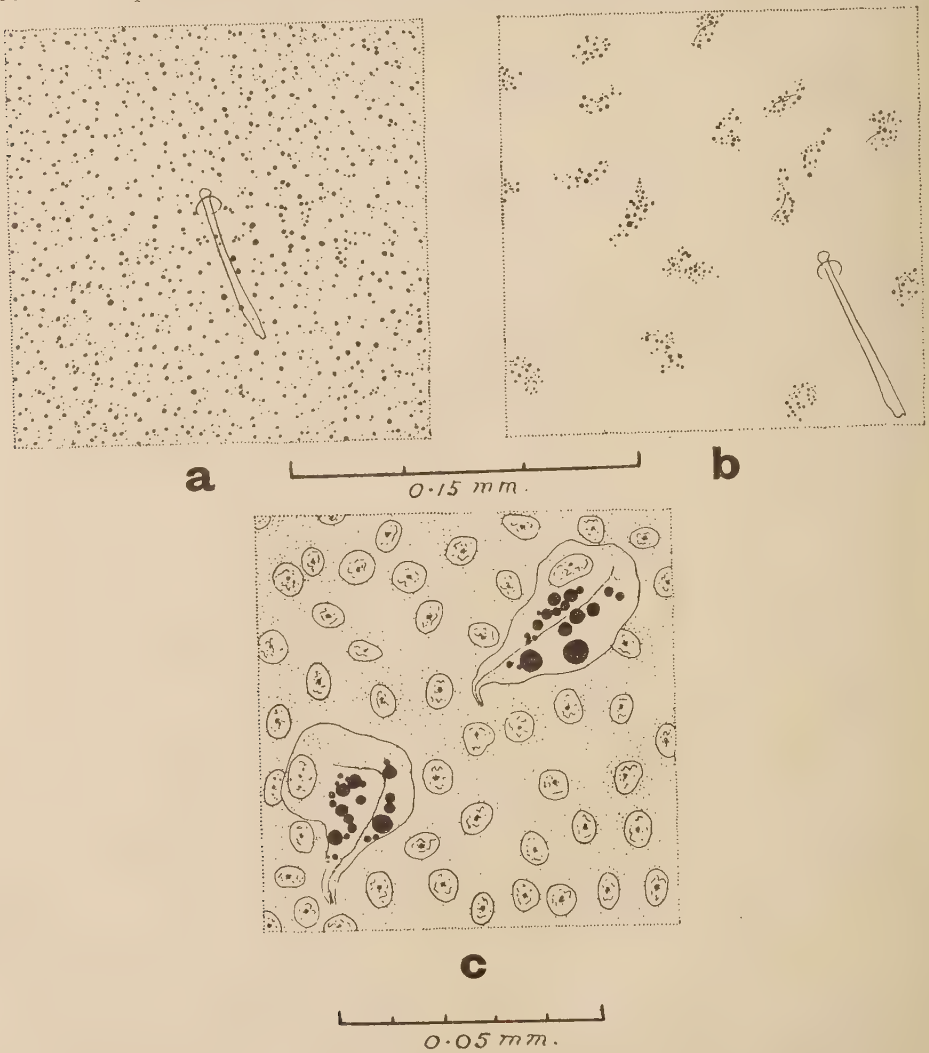

Fig. 6. A, surface view of abdominal cuticle of adult *Rhodnius* exposed to P31 plus 5 per cent. oleic acid for 24 hours one day after moulting; oil droplets in epidermal cells. B, the same at four days after moulting; oil droplets in the dermal glands only. C, detail of epidermis and dermal glands in adult similarly treated one month after moulting.

thus stand out conspicuously. The blackened oil may sometimes be seen as a fine thread in the duct of the glands. In adults one or two months after moulting, absorption of oil is likewise almost confined to the dermal glands (fig. 6, C).

Effect of Fatty Acids and other Polar Substances added to Pyrethrum in Paraffins and other Oils.

The foregoing histological observations show that oleic acid passes through the cuticle to the epidermis very readily and that its addition to paraffins or neutral fats greatly increases the rate of oil absorption. The effect of such additions to the speed of action of pyrethrum was therefore tested. Exact comparisons are made difficult by the individual variations already noted (p. 209). The procedure has been to compare two solvents at a time on two sets of six insects. The thickness of the cuticle can be judged approximately by examination of the living insect. Comparable insects were therefore distributed in the two sets and the median values for the time of complete paralysis recorded in each set. Only very large differences can be regarded as significant. The results are summarised in Table I which shows the time required for complete paralysis in 5th stage nymphs treated with 2 per cent. pyrethrins in the various media.

TABLE I.

White oil (P31)	12	hrs.	P31+5% caproic acid	3¾	hrs.
Oleic acid	4½	,,	,, valeric acid	3¾	,,
P31+5% oleic acid	4	,,	,, butyric acid	6½	,,
,, linoleic acid	3½	,,	,, "Aerosol OT"... ...	3¾	,,
,, lauric acid	4¾	,,	Olive oil	over 24	,,
,, pelargonic acid... ...	4½	,,	,, +5% "Aerosol OT"...	8	,,

We have seen that the average time for complete paralysis in 5th stage nymphs with the cuticle fully stretched, exposed to 2 per cent. pyrethrins in P31 was 45 minutes (p. 211). In comparable insects, exposed to 2 per cent. pyrethrins in P31+5 per cent. oleic acid the average time was 25 minutes.

In the adult type of cuticle the addition of oleic acid has no demonstrable effect. In one series, tested at one month after moulting, the time required for complete paralysis, using 2 per cent. pyrethrins, was 10½ hours in both P31 and P31+5 per cent. oleic acid.

Discussion.

Immersion of the louse in mixtures of oil and alcohol which separate in contact with water prove that, in regions where an exocuticle is poorly developed or wanting, the lipoid in the epicuticle constitutes the barrier between the oil and the water in the insect. This lipoid is more readily permeated or dissolved by the lighter oils. The lipoid layer has long been recognised as important in water conservation (Kühnelt, 1928). Insects which have been immersed for some time in paraffins or other fat solvents show an increase in the rate of water loss by evaporation (Hurst, 1942). If the lipoid is extracted with chloroform from the cuticle of the silkworm larva, the permeability to acids and alkalies is greatly increased (Klinger, 1936). O'Kane *et al.* (1940) who found that low boiling petroleum (98–153°C.) passes more rapidly through the isolated pronotum of the cockroach than higher boiling petroleum (199–255°C.) attribute this to differences in solvent properties for the wax in the epicuticle. Hoskins (1940) regards the lipoid layer as controlling the entry of insecticides.

When pyrethrum extract is dissolved in the lighter oils, it penetrates the nymphal cuticle of *Rhodnius* more readily than in the heavier oils. That this difference is likewise due in part to the greater solubililty of lipoid in the lighter oil is suggested by the fact that previous extraction of the epicuticle with petroleum ether acclerates the subsequent rate of entry of pyrethrum in a heavy oil. But this action on the epicuticular lipoid cannot be the sole factor that determines the rate of entry. For the great differences between insects with a thin and a thick endocuticle prove that the endocuticle is responsible for a very large part of the resistance. These differences are not so great when the pyrethrum is dissolved in a light oil. The light oil must therefore penetrate the endocuticle also more rapidly than the heavy oil. It is possible that action on lipoids in or over the cytoplasmic processes in the pore canals may be a factor. Hurst (1942) has likewise shown that the permeability of the endocuticle is increased by oils, although to a less extent than that of the epicuticle.

The great influence of cuticle thickness on the rate of entry of pyrethrum and the extent to which this thickness is influenced by the age and nutrition of the insect may be important factors in assaying the efficiency of pyrethrum preparations. Among other authors, Robinson (1942) and Hurst (1942) have demonstrated the slower rate of entry through the presumably thicker cuticle of older insects. Klinger (1936) found a three-fold increase in the resistance of larvae of *Dendrolimus pini* during the last instar as the endocuticle increases in thickness. Simanton and Miller (1937) have shown that young house flies (1½ hours old) are much more quickly paralysed by pyrethrum than flies 2–5 days old.

That pyrethrum will enter through the insect cuticle has long been established. What elements in the cuticle are concerned is less certain. O'Kane *et al.* (1933) found that the intersegmental regions of the thorax and abdomen of mealworms and cockroaches are more sensitive to pyrethrum extracts than the sclerotized regions. Shepard (1939) considers it likely that penetration is chiefly through the thin walls of the pores at the base of sensory hairs and elsewhere (*cf.* Wilcoxon & Hartzell, 1933). Klinger (1936) attributes the greater resistance of Noctuid caterpillars as compared with some hairy caterpillars or with the larva of *Smerinthus ocellatus* to the presence of hair sockets or numerous dermal sense organs in the latter insects ; and he ascribes the greater sensitiveness of adult insects to the same causes.

Klinger (1936) assumes that when such organs are absent the poison passes through the outermost layers of the cuticle to the pore canals, and then to the cells along the cytoplasmic strands which these canals contain. *Smerinthus* larvae with numerous broad pore canals are more sensitive than *Carpocapsa* larvae with few canals. But he recognises that there are other factors also, presumably in the physico-chemical nature of the cuticle or of the lipoid layer. Thus the larva of *Lymantria monacha* is more resistant than that of *Dendrolimus pini* although there is no obvious difference in the pore canals, and the cuticle is actually thinner.

The present work has shown that the stretched cuticle is more permeable to pyrethrum than the unstretched cuticle of equal thickness. And this has been attributed to the enlargement of the pore canals on stretching. If the histological demonstration of oil absorption through the cuticle can be accepted as an index of where the entry of pyrethrum is taking place, this entry occurs through the general cuticle and epidermis in recently formed or stretched cuticle ; in the older or less stretched nymphs of *Rhodnius* it takes place chiefly around the bristles ; in the older adults of *Rhodnius* there is no evidence of absorption at the base of the bristles or through the general cuticle of the abdomen, but much absorption by the dermal glands. These few observations show what great differences are likely to exist in different insects and in different parts of the body.

Lastly it has been shown that oleic and other fatty acids increase the absorption of paraffins and neutral fats through the cuticle* and accelerate the entry of dissolved pyrethrum. This effect is more evident in the nymphal cuticle of *Rhodnius*, where a thick endocuticle is present, than in the adult. Perhaps the effect is due to the enhanced ability of the oil to spread over surfaces moist with water. (A drop of liquid paraffin (P31) coloured with Black Sudan B and placed on a piece of stout blotting paper saturated with water, will appear at the lower surface in about 1½ hours ; a similar drop containing 5 per cent. of oleic acid will appear below in 15 minutes.) Perhaps it is due to a tendency of the oil to emulsify in contact with the cytoplasm of the pore canals. (P31 containing 5 per cent. of oleic acid or 5 per cent. of Aerosol OT undergoes partial emulsification on coming into contact with phosphate buffer at *p*H 8·0.)

Sullivan, Goodhue & Fales (1941) have recently shown that the addition of fatty acids to orthodichlorobenzene greatly increases its toxicity to house flies. In *Rhodnius* no increase in the rate of action of pyrethrum on adding oleic acid could be demonstrated when the mixture was sprayed on the whole insect.

Summary.

Insects immersed in oils exude minute droplets of water over the surface of the cuticle. These appear more rapidly in light oils than in heavy oils and are more numerous in young insects than in old. Immersed in mixtures of oils and alcohols which separate in contact with water they show a vigorous effervescence at those regions where the mixture penetrates most rapidly to the water in the cuticle. There is a delay of varying duration at different parts of the cuticle when heavy oils are used. This delay disappears if the lipoid layer is first extracted with petroleum ether.

Factors controlling the rate of entry of pyrethrum through the cuticle have been studied by the application of pyrethrum in oil to a restricted area of the abdomen of nymphs and adults of *Rhodnius*. Entry is more rapid in light than in heavy petroleum oils ; it is much accelerated if the cuticle is first treated with petroleum ether. Entry is very slow in vegetable oils. There are great individual variations, due chiefly to the thickness of the endocuticle, which in turn is determined by the size of meal taken before moulting, the age and the amount of food taken after moulting, and the degree of stretching of the cuticle. There is evidence that the pore canals are important in the passage of pyrethrum through the endocuticle.

Histological examination of the integument shows that in the nymph of *Rhodnius* oils are taken up first by the epidermal cells in the zone around the bristles ; later by the general epidermis. The uptake of oil is greatly increased if 5 per cent. of oleic acid is added to refined petroleum. In the adult *Rhodnius* soon after moulting, oils are taken up by the general epidermis. In old insects they are taken up solely by the dermal glands. There is no visible entry through the sockets of the bristles.

The entry of pyrethrum in oils is accelerated by the addition of oleic or other fatty acids.

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I am indebted to Dr. H. Hurst for kindly allowing me to read his work before publication and for some valuable criticisms ; to Dr. J. T. Martin for preparing an

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* The recorded observations do not entirely prove that oleic acid increases the absorption of these other oils. The results might be due to preferential absorption of oleic acid from the mixture. But the fact that similar (though less marked) results are obtained with a wetting agent such as Aerosol OT, suggests that an increased absorption of paraffin has been induced (*cf.* Frazer, Stewart & Schulman, 1942). When the cuticle is very thin, paraffin or olive oil alone may be absorbed in small amounts (fig. 5, C).

alcoholic extract of pyrethrum with known pyrethrin content ; to Dr. F. Tattersfield and Dr. Martin for chemical advice ; and to Miss W. Wall for her careful technical assistance.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st April and 30th June, 1942 :—

Mr. S. P. V. Bray :—46 Elaterid larvae ; from England.

Chief Entomologist, Pretoria :—90 Coleoptera ; from South Africa.

Colonial Forest Resources Development Department :—9 Coleoptera and 2 early stages ; from Tanganyika Territory.

Department of Agriculture, British Honduras :—15 Orthoptera and 300 early stages.

Mrs. V. Dickson :—4 Orthoptera ; from Arabia.

Mr. R. G. Fennah, Imperial College of Tropical Agriculture :—35 Coleoptera ; from the British West Indies.

Mr. J. C. M. Gardner, Systematic Entomolgist :—13 Lepidoptera ; from the United Provinces, India.

Mr. G. H. E. Hopkins, Medical Entomologist :—28 *Glossina* ; from Uganda.

Mr. T. H. Jacob :—20 Curculionidae ; from England.

Mr. H. C. Jennings :—3 Culicidae and 4 other Diptera ; from England.

Mr. J. F. Perkins :—12 Coleopterous larvae ; from England.

Mr. R. T. M. Pescott, Entomologist :—6 Coleoptera and 2 tubes of Aleurodidae ; from Victoria, Australia.

Rhodesia Museum, Bulawayo :—207 Coleoptera ; from South Africa.

Mr. F. A. Squire, Government Entomologist :—6 Diptera, 10 Coleoptera, 80 Parasitic Hymenoptera, 3 other Hymenoptera, 15 Rhynchota and 8 Leeches ; from Sierra Leone.

Mr. D. A. Tidman :—1 species of Aphidae ; from England.

THE MACROSCOPIC DIFFERENTIATION OF ANOPHELINE EGGS ACCORDING TO THEIR PATTERN ON THE SURFACE OF WATER.

By Z. Saliternik.

(*District Inspector, Malaria Control Bureau, Jerusalem.*)

(Plate V.)

Thus far nine species of *Anopheles* have been found in Palestine. These, in order of frequency and importance, are: *A. elutus*,* Edw., *A. superpictus*, Grassi, *A. sergenti*, Theo., *A. multicolor*, Camb., *A. claviger*, Mg. (*bifurcatus*, auct.), *A. algeriensis*, Theo., *A. hyrcanus*, Pall., *A. pharoensis*, Theo., and *A. coustani*, Lav. (*mauritianus*, Grp.).

The morphological characters of the eggs of these species have been described and are well known. Workers have, however, overlooked the fact that their eggs arrange themselves on water in specific patterns, determined apparently by their structure. Observations made during 1939–41 have shown that, if a number of eggs is placed on a drop of water, they assume a pattern characteristic of the species. This pattern arrangement makes possible a macroscopic differentiation of species in the field.

Observations have been made on ovipositions of all the species, but more particularly of *A. elutus* (188 ovipositions), *A. sergenti* (365 ovipositions), *A. superpictus* (149 ovipositions) and *A. multicolor* (51 ovipositions). These results indicate that these species arrange themselves into two types of patterns :—

i. Eggs arranged in parallel patterns. To this group belong those species that breed in open unshaded water : *A. elutus*, *A. superpictus*, *A. multicolor*.

ii. Eggs arranged in angular patterns, the eggs lying at an angle to one another, in the form of stars, etc. This group comprises the six remaining species, all of which prefer shaded places for their development.

The species of the first group can be readily separated by differences within the pattern :—

The eggs of *A. elutus* arrange themselves in long parallel rows and seem to the naked eye to have a space between the individual eggs, the appearance being of rows, ash grey in colour. The autumn eggs with small floats change their patterns to the star form, but the ash grey colour differentiates them from those of other species having that pattern.

The eggs of *A. superpictus* are dark in colour, and the groups do not usually arrange themselves in parallel rows. The individual eggs in a group are separated from one another by a narrow space.

The eggs of *A. multicolor* are black and are deposited so close to one another that it is difficult to differentiate individual eggs. The ovipositions have the appearance of long ribbons.

The eggs of *A. sergenti* belong to the angular type of pattern and can thus be readily differentiated from those of *A. superpictus*.

In practice, the simplest procedure is to pick up some eggs on the point of a needle, deposit them on a drop of water on a glass slide and tap the slide gently. The eggs arrange themselves in their characteristic pattern. The differentiation can thus be made without special apparatus.

Plate V illustrates the typical appearance of the different species of eggs. They were made with an ordinary Kodak camera attached to the No. 10 or 15 ocular of a Zeiss microscope with a number 8 objective.

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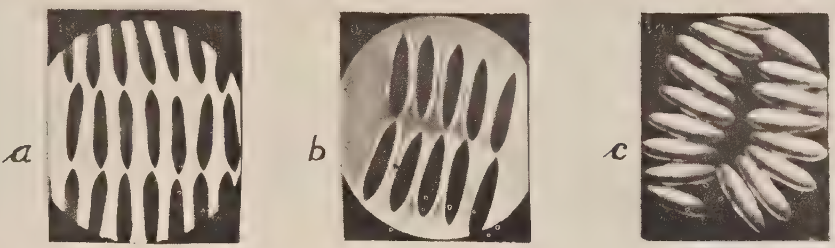
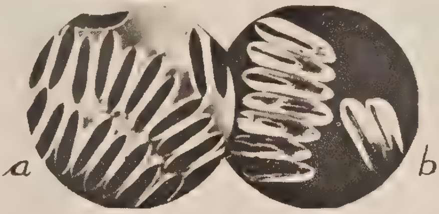
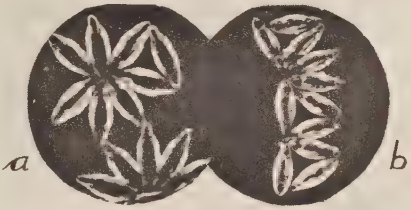
* The correct name for this species is *Anopheles maculipennis* var. *sacharovi*, Favr.—Ed.



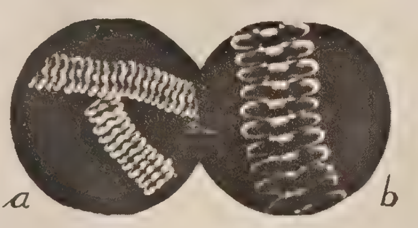
A. elutus, Edw.
a, usual dorsal aspect; b, c, winter eggs, unusual dorsal aspect.



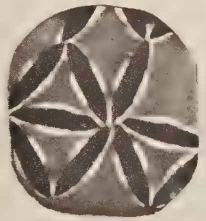
A. superpictus, Grassi,
a, usual dorsal aspect.
b, unusual dorsal aspect.



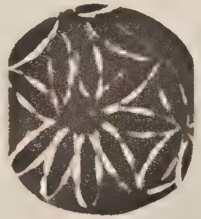
A. sergenti, Theo.
a, usual dorsal aspect.
b, unusual dorsal aspect.



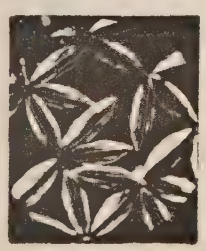
A. multicolor, Camb.
a, b, dorsal aspect.



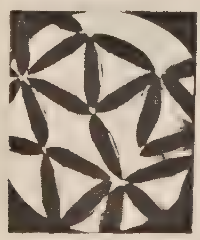
A. claviger, Mg.
Dorsal aspect.



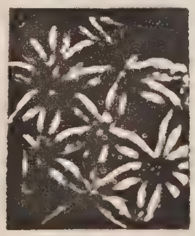
A. pharoensis, Theo.
Dorsal aspect.



A. coustani, Lav.
Dorsal aspect.



A. hyrcanus, Pall.
Dorsal aspect.



A. algeriensis, Theo.
Dorsal aspect.

EGGS OF *ANOPHELES* IN PALESTINE.

A TACHINID PARASITIC ON *PLUTELLA MACULIPENNIS*, CURT.

By F. I. van Emden.

Imperial Institute of Entomology.

Dr. R. H. Le Pelley has reared in Nairobi a number of specimens of a new Tachinid from the diamond-back moth (*Plutella maculipennis*, Curt.).

Cadurcia plutellae, sp. n. ♂♀.

♂. *Head* black, the pollinosity of the face, lower half of the parafrontalia and lower half of the posterior orbits inconspicuous, but appearing almost silver-white in certain directions. Eyes bare. Frons one-fifth to one-sixth head-width (slightly less than one-half eye-width) above middle, very slightly dilated to vertex, moderately dilated to lunula ; face moderately dilated with the sides almost straight to the lower margins of the eyes, which are separated by half the head-width ; parafrontalia and interfrontalia somewhat narrowed to about middle, parallel-sided from there to base, the interfrontalia velvety blackish-brown, somewhat wider than the parafrontalia, the latter with about six inclinate and two reclinate setae, the parafacialia with 3–4 descending inclinate frontals, which reach the level of the apex of the second antennal joint. Antennae fuscous-black, third joint more than twice as long as wide, almost reaching level of lower eye-margins, falling short of mouth-margin by half its width, arista minutely pubescent, the hairs shorter than its basal diameter, the basal fourth moderately incrassate. Parafacialia one-half, jowls fully as wide as the third antennal joint, vibrissae level with mouth-margin. Palpi fuscous, hardly projecting beyond mouth-margin.

Thorax black, with a usually strong brassy gloss and a very inconspicuous brownish pollinosity. 3+3 *acr* (the first of them smaller, the third at suture), 3+4 *dc*, 1+3 *ia*, 2 *ph* ; *prst* and *pra* considerably stronger than the first *post dc*, *sa* and posterior postalar strong, two humerals, two *npl* and anterior postalar moderately strong ; scutellum setulose on dorsal surface and sides, the basal and subapical marginals strong, the lateral marginal moderately strong, the apicals rather weak, cruciate, usually a pair of preapical discals present. Propleural and prostigmatal setae present, anterior mesopleural fine to indistinct, hind margin of mesopleura with three finer setae on upper fourth, which are somewhat curved downward, and three strong and many fine ones on the lower three-fourths, pteropleura with two setae and a number of setulose hairs on anterior part of infrasquamal ridge* ; *stpl* 1–1—1 ; hypopleurals five.

Abdomen black, with a more or less distinct brassy gloss and very inconspicuous brownish pollinosity, the first and second segments without pale dust, the third and fourth each with an anterior band of pale golden pollinosity, which reaches or slightly passes middle, but which is narrowed towards the sides of the second segment, where it only reaches the basal third. First segment without, second with a more or less distinct pair of median marginals, third with a complete row, fourth with a discal and a marginal row of about three pairs ; ventral surface of the third segment with a not very dense, moderately large *Sturmia*-spot. ♂ terminalia see Fig. 1.

Legs black, the pulvilli greyish white. Claws and pulvilli longer than the last tarsal joint, the pulvilli much longer than wide. Fore femora with 6–7 setae in the *d* and *pd* rows and about twelve rather long ones in the *pv* row, fore tibiae with two

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* The embossed part on the upper end of the pteropleura which connects the latter with the supraspiracular convexity.

p setae (beyond middle and at apical quarter); mid femora without distinct *a* setae, with 3–4 rather long *pv* in basal half and a strong *p* preapical, mid tibiae without an *av*, with one usually rather strong *ad* and 2–3 *pd*; hind femora with about 12 *ad* setae, 2–3 *av* near base and a rather long and strong *av* preapical, 3–4 long *pv* in basal half and a small *d* and *pd* preapical, hind tibiae with 1–2 *av* setae, a not very dense row of *ad* setae, one of which is longer, and an irregular *pd* row, in which three setae are longer.

Wings strongly infuscate on anterior and basal part, distinctly milky on hind and apical parts, the milky area extending well into apex of R_5 but not of discal cell and reaching almost base of axillary lobe; C_1, C_2 and *Sc* fuscous, costal border up to apex of r_{2+3} strongly infuscate, R_3 distinctly brownish up to apex of r_{4+5}, r_1 ending far beyond *r–m*, the latter well before middle of discal cell. r_{2+5} almost straight though slightly sinuate towards apex, R_5 virtually closed in margin, not very far from wing tip, *m-m* rather strongly oblique and sigmoid; veins bare but for one setula at the base of r_{4+5}. Calyptrae translucent fuscous with fuscous border and fringe. Halteres infuscate.

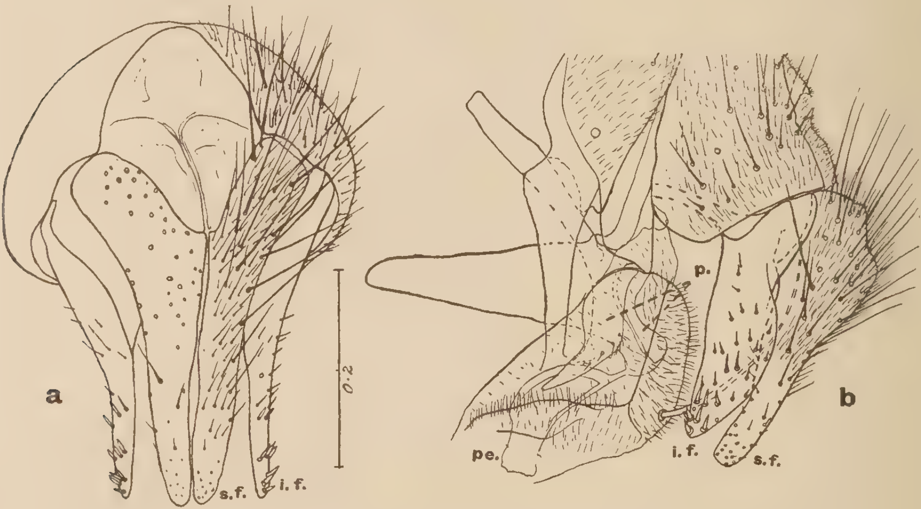

Fig. 1. *Cadurcia plutellae*, sp. n., terminalia of ♂. *a*, posterior view; *b*, lateral view; *s.f.* superior forceps; *i.f.* inferior forceps; *p.* anterior and posterior parameres; *pe.* penis. (Setae and hairs largely omitted on left side of fig. 1*a*.)

♀. Frons almost one-third head-width at lunula, evenly narrowed to vertex where it is somewhat more than one-fourth head-width; parafrontalia very slightly, interfrontalia distinctly narrowed above, the former almost as wide as the latter at lunula, distinctly wider than them in front of ocelli, parafrontalia with only three inclinate setae (in addition to the descending ones), with two strong proclinate orbital setae. Abdomen without a *Sturmia*-spot. Claws and pulvilli shorter than the last tarsal joint, the pulvilli not longer than wide; fore femora with fewer *pv*, hind femora with fewer *ad* setae; mid femora with two rather small *av* setae near base and 1–2 rather strong *a* setae towards middle. Wings only slightly smoky towards costa.

Length: 2·7–3·7 mm., of wings, 2·5–3·5 mm.

KENYA: Nairobi, ix.41, ex *Plutella maculipennis* (*R. H. Le Pelley*) ♂ type, 9♂, 17♀ paratypes. Type and paratypes in B.M., other paratypes returned to Dr. Le Pelley.

Cadurcia plutellae is considerably smaller than all the known species, which vary between 4 and 7 mm., but in a parasite this does not necessarily imply that it is distinct from them. However, in *C. semiviolacea*, Villen., the eyes are hairy, in *borbonensis*, Villen., and *leefmansi*, Baran., the *Sturmia*-spot of the male is absent and the second abdominal segment is adorned with an interrupted band of pale dust along fore margin, in *lucens*, Villen., and *versicauda*, Curr. (described as a *Sturmia* like the other species of Curran which are mentioned in the following lines) the mid tibiae have a *v* seta, in *albicauda*, Curr., the mid tibiae are devoid of an *ad* seta; in *casta*, Rond., and *vanderwulpi*, Bar., the calyptrae of the female are whitish-ochreous, in *zetterstedti*, B. B., the second abdominal segment has no marginal setae, and in *depressa*, Villen., and *auratocauda*, Curr., the dorsum of the fourth abdominal segment is wholly (or almost wholly) pale-dusted. There only remains *C. fascicauda*, Curr., from which *plutellae* is not so easily distinguished, the genitalia of *fascicauda* being unknown. According to Curran, the third and fourth abdominal segments of *fascicauda* are white- (not golden-yellow) pollinose and the pollinosity extends to the apical third (in *plutellae* to middle), the costal border of the wings has a brownish tinge on the basal half only (whereas in *plutellae* it is strongly infuscate up to the apex of r_{2+3}), R_5 is narrowly open (virtually closed in margin in *plutellae*), and the lower calyptra is brown (fuscous in *plutellae*). These deviations from the present specimens in conjunction with the larger size (6–6·5 mm.) make it certain that *fascicauda* is a species distinct from the one reared from *Plutella maculipennis*, and the economic importance of the host renders a description of the new species desirable.

A METHOD OF TRANSPORTING LIVING MOSQUITO LARVAE.

By D. J. Lewis, M.A., F.R.E.S.

Entomologist, Sudan Medical Service.

Outbreaks of yellow fever in the Anglo-Egyptian Sudan and Uganda in 1940 emphasised the necessity for the mosquito control measures which are in force to prevent the disease from reaching Egypt or the East African ports. Edwards (1941, Mosquitoes of the Ethiopian Region, III, p. 3), referring to yellow fever, states that " it would seem that most of the common biting mosquitoes of West Africa are to be regarded as potentially dangerous." This statement applies also to north-east Africa. For the further planning of control measures, more information is required as to which mosquitos can act as vectors. Transmission experiments can usually be carried out only in a few specially equipped laboratories, so that mosquitos must sometimes be transported over great distances. A convenient method of doing this is to carry several thousands of living larvae which can provide a supply of adults for experiments. The writer has, for several years, used the simple method described below and found it effective in the hot dry climate of the northern Sudan. Recently it proved useful for sending larvae of species of *Aëdes* to the Yellow Fever Research Institute at Entebbe.

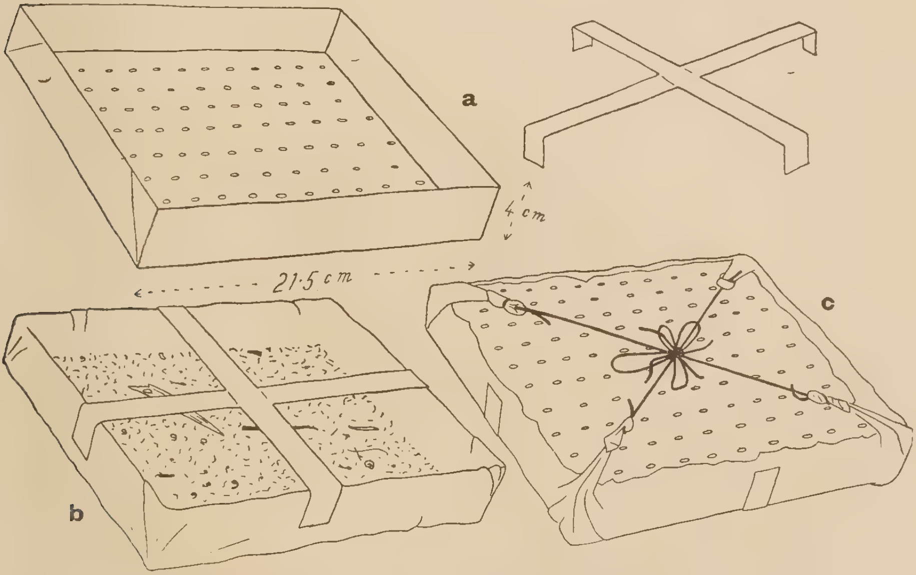

Fig. 1. Trays for transporting larvae : *a*, empty tray with cross-piece ; *b*, tray with larvae, ready for packing ; *c*, tray inverted to show fastenings.

Larvae are stranded on a wet surface in a cool damp atmosphere and can be carried under these conditions for many hours or even several days. Perforated trays are made from the metal of petrol tins as shown in Fig. 1. A piece of cloth 44 cm. square is laid over each tray and tied underneath it. Water containing the larvae is poured into the tray and drains away, leaving the larvae stranded. A metal cross-piece laid on the tray serves to support another tray above it. Eight trays can be placed in a four gallon petrol tin which is then closed with a lid. In hot weather a wet towel may be wrapped round the tin.

Adult mosquitos often emerge in the tin during a journey. When this is undesirable, pupae may be removed before packing, or the tin opened in a cage on arrival.

If gelatinous algae are present in the water from which the larvae are taken, the algae should be removed because they form a layer that kills the larvae.

NEW SPECIES OF *PODAGRICA* (HALTICINAE, COLEOPTERA) FROM AFRICA.

By G. E. Bryant, F.R.E.S.

Imperial Institute of Entomology.

The genus *Podagrica* occurs in very large numbers in Africa, both as regards species and specimens, and from the records we already have, at least twelve are recorded as doing damage to cotton, *Hibiscus* and other plants. A list of these is given and also a list of described African species, there being at present no up-to-date catalogue of the Halticinae.

Weise, in Naturgeschichte der Insecten Deutschlands, **26,** 1886, p. 681, sinks the genus *Nisotra*, Baly. 1864, to *Podagrica*, Foudras, 1860, quite rightly. There are already 39 described African species, to which I now add eight new ones. There can be no doubt that the whole genus will prove to be destructive to various crops. It ranges from Europe to Australia, but does not occur in North or South America. The species are very difficult to define, almost as much so as the genus *Haltica* ; the species having the prothorax fulvous and the elytra blue form the largest group ; another group is entirely flavous or fulvous, and a third small group has spots or slight markings.

The following is a list of the species of *Podagrica* that have been forwarded from time to time to the Imperial Institute of Entomology, and recorded as doing damage.

P. dilecta, Dalm.—Sierra Leone, 13.ii.1924 (*E. Hargreaves*). Damaging crops. Uganda, 2.iii.1925 (*H. Hargreaves*), on *Sida cordifolia*.

P. maculata, Wse.—Nyasaland, v.1916 (*C. Mason*), shot-holing *Hibiscus* ; Pretoria, xi.1928 (*H. K. Munro*), on *Hibiscus* and *Pavonia*.

P. o'neili, Jac.—Bloemfontein, x.1914, feeding on hollyhock.

P. pallida, Jac.—Sudan, xi.1916 (*J. W. Cowland*), on Bamia (*Hibiscus*).

P. puncticollis, Wse.—Sudan, i.1927, on *Abutilon* sp., vii.1926 (*J. W. Cowland*), on Bamia (*Hibiscus*) ; Uganda, 23.x.1925 (*G. L. R. Hancock*) on *Abutilon* ; Tanganyika, vii.1922 (*A. H. Ritchie*), on *Malva*.

P. sjöstedti, Jac.—Uganda, x.1925 (*J. C. Hopkins*), on *Hibiscus* ; Uganda, 7.xi.1921 (*H. Hargreaves*), on " Kansambur."

P. spadicea, Dalm.—Sierra Leone, 20.viii.1924 (*E. Hargreaves*), on *Hibiscus*.

P. sudanensis, Heik.—Sudan, xi.1926 (*W. Ruttledge*), on Hanbuk (*Abutilon glaucum*, Webb.).

P. testacea, Chap.—Nyasaland, iii.1915 (*C. Mason*), on cotton leaf ; Natal, 3.xi.1891 (*Sir G. A. K. Marshall*), on *Malva*.

P. uniformis, Jac.—Gold Coast, ix.1920 (*W. H. Patterson*), on Ochra and *Hibiscus*, vii.1922 (*Dr. J. W. Scott Macfie*) on Ochra ; S. Nigeria, vii.1913 (*W. A. Lamborn*), eating holes in leaves of a fibre plant, *Wiesadula rostrata*.

List of African Species of *Podagrica*.

Podagrica africana, **n. n.** for *P. ferruginea*, Wse. nec Brancsik.

Podagrica angustula, Wse.—Arch. Naturgesch., **68,** 1902, p. 167. Africa.

Podagrica apicalis, Jac.—Proc. Zool. Soc. Lond., **1899,** p. 355. West Africa.

Podagrica aruwimiana, Wse.—Wiss. Ergebn. dtsch. Zent. Afr. Exped., **4**, 1912, p. 158. Central Africa.

Podagrica bevinsi, sp. n.—Cape Colony.

Podagrica coerulea, sp. n.—Uganda.

Podagrica congoensis, Jac.—Proc. Zool. Soc. Lond., **1899**, p. 355. West Africa.

Podagrica continentalis, Wse.—Ann. Soc. ent. Belg., **1911**, p. 169. East Africa.

Podagrica corpulenta, Wse.—Arch. Naturgesch., **70** (1), 1903, p. 51. Africa.

Podagrica costatipennis, Jac.—Proc. Zool. Soc. Lond., **1899**, p. 353. West Africa.

Podagrica cupripennis, sp. n.—West Africa.

Podagrica dalmani, Jac.—Stettin. ent. Ztg., **64**, 1903, p. 306. Cameroons.

Podagrica decolorata, Duv.—Ann. Soc. ent. Belg., **36**, 1892, p. 60. Congo.

Podagrica deserticola, Wse.—Beitr. Land- u. Süsswasserfauna Dtsch.-Südw. Afr. **1**, 1918, p. 268. Africa.

Podagrica dilecta, Dalm.—Analecta ent., 1823, p. 81. Sierra Leone (*rufiventris*, Sturm—Cat. 1826, p. 147. Guinea).

Podagrica ferruginea, Brancsik—Jahresheft. naturw. Ver. Trencsin., **1897**, p. 325. Nossi Bé.

Podagrica ferruginea, Wse. (nec Brancsik 1897).—Arch. Naturgesch., **68**, 1902, p. 166. Africa.—See *P. africana*, Bryant.

Podagrica glabrata, Jac.—Proc. Zool. Soc. Lond., **1899**, p. 349. Natal.

Podagrica impressipennis, Jac.—Trans. Ent. Soc. Lond., **1903**, p. 12. Natal.

Podagrica kibonotensis, Wse.—Wiss. Ergebn. Exped. Kilimandjaro Meru, Bd. 7, no. 12, 1909, p. 218. East Africa.

Podagrica lineata, Wse.—Arch. Naturgesch., **68**, 1902, p. 167. Africa.

Podagrica maculata, Wse.—Arch. Naturgesch., **68**, 1902, p. 167. Africa.

Podagrica maculiceps, Bryant—Ann. Mag. nat. Hist., (11) **8**, 1941, p. 291. Kenya.

Podagrica marshalli, sp. n.—Beira, Portuguese E. Africa.

Podagrica melanopa, Wse.—Arch. Naturgesch., **83** (A), 1919, p. 198.

Podagrica nigriceps, sp. n.—Uganda, Kenya.

Podagrica nigriventris, Jac.—Ann. Soc. ent. France, **76**, 1908, p. 518. East Africa.

Podagrica o'neili, Jac.—Trans. Ent. Soc. Lond., **1906**, p. 21. Cape Colony.

Podagrica ornata, Jac.—Ann. Soc. ent. France, **76**, 1908, p. 518. East Africa.

Podagrica ovatipennis, Jac.—Proc. Zool. Soc. Lond., **1899**, p. 352. West Africa.

Podagrica pallida, Jac.—Ann. Mus. Genova, **39**, 1898, p. 527. Somaliland.

Podagrica pallidipes, sp. n.—Kenya, Uganda.

Podagrica puncticollis, Wse.—Arch. Naturgesch., **68**, 1902, p. 166. Africa.

Podagrica quadriplagiata, Jac.—(*Mantura*) Trans. Ent. Soc. Lond., **1895**, p. 321. Natal.

Podagrica risbeci, Bryant—Proc. R. Ent. Soc. Lond., (B) **10**, 1941, p. 212. Senegal.

Podagrica sjöstedti, Jac.—Ark. Zool., **1**, 1903, p. 230, pl. X, fig. 6. Cameroons.

Podagrica spadicea, Dalm.—(*Podontia*) Analecta ent., 1823, p. 80. Sierra Leone.

Podagrica spilota, Wse.—Arch. Naturgesch., **83** (A) Heft 4, 1919, p. 198. East Sudan.

Podagrica suahelorum, Wse.—Wiss. Ergebn. Exped. Kilimandjaro Meru, Bd. 7, no. 12, 1909, p. 218. East Africa.

Podagrica sudanensis, Heik.—MS. name, ? published. Sudan.

Podagrica suzannae, Laboiss.—Rev. Zool. Bot. afr., **32,** 1939, p. 403. Ruanda.

Podagrica testacea, Chap.—Ann. Mus. Genova, **15,** p. 12. East Africa.

Podagrica theobromae, Laboiss.—Bull. Mus. Paris, **1920,** p. 31. San Thomé.

Podagrica turneri, sp. n.—Kenya.

Podagrica unifasciata, Jac.—Proc. Zool. Soc. Lond., **1899,** p. 353. West Africa.

Podagrica uniformis, Jac.—Proc. Zool. Soc. Lond., **1899,** p. 354. West Africa.

Podagrica viridipennis, sp. n.—Kenya.

Podagrica weisei, Jac.—Trans. Ent. Soc. Lond., **1906,** p. 21, pl. 3, fig. 2. Beira, Portuguese E. Africa.

HALTICINAE.

Podagrica pallidipes, sp. n.

Ovate, metallic dark green, the legs and five basal segments of the antennae fulvous, prothorax finely punctured, the elytra with double irregular longitudinal rows of punctures. Length : 3·5 mm.

Head impunctate, the frontal half fulvous, the basal portion behind the insertion of the antennae metallic green. *Antennae* not extending to the middle of the elytra, the five basal segments fulvous, the remainder fuscous, the first segment longer and more dilated than the second, the third more slender and a third longer than the second, the fourth slightly shorter than the third, and the fourth to the tenth about equal, the eleventh longer and acuminate. *Prothorax* dark metallic green, transverse, the sides contracted in front, and the anterior angles prominent, finely but not closely punctured, the anterior margin with a short longitudinal impression on each side. *Scutellum* metallic green, triangular impunctate. *Elytra* dark metallic green, oblong, rounded at the apex, the punctures forming irregular double longitudinal rows. *Legs* entirely pale fulvous, the male with the first segment of the anterior tarsus dilated. *Underside* dark metallic green, the apical ventral segment fulvous, with scattered punctures.

KENYA : Kakumega, i-ii.1916 (*H. J. A. Turner*) 1 specimen ; Maragoli, x.1924 (*Dr. van Someren*) 1 specimen ; UGANDA : Kampala, 3,780 ft., xi-xii.1920 (*A. F. J. Gedye*) 1 specimen ; Kampala, 1921, G.73 (*H. Hargreaves*), 1 specimen ; Masindi, 20.vi.1923 (*H. Wilkinson*), 1 specimen.

A very distinct species on account of its uniform metallic green colour, in structure allied to *P. dilecta,* Dalm.

Podagrica cupripennis, sp. n.

Elongate convex, head and prothorax flavous, the five basal segments of the antennae and the legs flavous, elytra deep bronze black, head and prothorax finely punctured, the elytra more strongly and with irregular double rows. Length : 4 mm.

Head flavous, strongly impressed between the antennae, a few strong punctures near the inner margin of the eyes, the basal portion with very fine punctures. *Antennae* extending a short way beyond the base of the elytra, the five basal segments flavous, the remainder black and more pubescent, the first segment the longest and more dilated. *Prothorax* flavous, very transverse, the sides straight but contracted in front, the anterior angles slightly produced, the anterior margin with a short longitudinal impression near the anterior angles, finely and irregularly punctured, the punctures slightly stronger than those on the base of the head. *Scutellum* bronze black, impunctate. *Elytra* bronze black, elongate, slightly wider just behind the middle, and then gradually rounded to the apex, somewhat strongly punctured in double irregular longitudinal rows, the punctures stronger than on the prothorax. *Legs* flavous, the first segment of the anterior tarsus more dilated in the male. *Underside* black, the first ventral segment of the abdomen the longest, the second to the fourth short and about equal to each other, clothed with scattered punctures.

WEST AFRICA: Principe I., 29.xii.1932 (*W. H. T. Tams*), 9 specimens.

A very distinct species, on account of its more elongate shape and its deep bronze colour, the sides of the elytra are more parallel than any of the species with blue elytra.

Podagrica bevinsi, sp. n.

Ovate, head deep fulvous, prothorax, antennae and legs flavous, elytra metallic green, prothorax strongly punctured, and the elytra strongly punctate-striate. Length: 2·5 mm.

Head deep fulvous, nitid, impunctate. *Antennae* flavous, not extending to the middle of the elytra, the basal segment the longest, about equal to the second and third together, the third to the sixth more slender, the seventh to the eleventh more dilated, and about equal to each other. *Prothorax* flavous, very transverse, the sides rounded and feebly margined, widest at the middle, with large scattered punctures, and a short longitudinal impression at each side on the basal margin. *Scutellum* metallic green, nitid, impunctate. *Elytra* metallic green, the sides parallel, behind the middle tapering and rounded to the apex, very strongly punctate-striate, with the intervals nitid. *Legs* flavous, the male with the basal segment of the anterior tarsi more dilated. *Underside* black, the ventral segments of the abdomen with shallow punctures, the first segment very long, about equal to the second to fourth together.

CAPE COLONY: Table Mountain, 1906 (*W. Bevins*), 12 specimens.

This small species somewhat allied to *P. sudanensis*, Heik., the type of which was returned before the war to the Imperial Institute of Entomology with this name, and I have no means of knowing if it has been published. It differs from *P. bevinsi* in the head and prothorax being flavous, the prothorax very finely punctured, the sides almost straight with the anterior angles produced, the punctures on the elytra are finer and the intervals less nitid, and the elytra less tapering at the apex.

Podagrica nigriceps, sp. n.

Ovate, head black, prothorax, the five basal segments of the antennae fulvous, elytra dark blue, prothorax very finely punctured, the elytra with the punctures stronger and in irregular double longitudinal rows. Length: 4–4·5 mm.

Head black, with a slight metallic tinge, with traces of very minute punctures, transversely impressed between the eyes. *Antennae* extending just beyond the base of the elytra, the first five segments fulvous, the remainder fuscous clothed with ashy pubescence, the first segment slightly longer than the second and more dilated, the third more slender than the second and slightly longer, the fourth about equal to the second, and about equal to each to the tenth, the eleventh longer than the tenth and acuminate. *Prothorax* fulvous, transverse, the sides rounded, slightly contracted in front, the basal angles acute, a short longitudinal feeble impression on the anterior margin near the angles, very finely but closely punctured. *Scutellum* blue black, triangular, impunctate. *Elytra* deep blue, the sides straight and rounded to the apex, the punctures forming irregular double longitudinal rows, the punctures stronger than on the prothorax. *Legs* fulvous. Male smaller and with the first segment of the anterior tarsi more dilated. *Underside* with the ventral segments of the abdomen fuscous, tinged with fulvous, rugosely punctured, the third and fourth segment short and about equal.

UGANDA: Kampala, 27.viii.1915 (*C. C. Gowdey*), 7 specimens; Kinganga, 30.iv.1927 (*H. Hargreaves*), 1 specimen; Mt. Elgon, 5,100–5,800 ft., 8–11.vi.1911 (*S. A. Neave*), 3 specimens; Mpanga Forest, 4,800 ft., 12–23.xi.1911 (*S. A. Neave*), 4 specimens; KENYA: Nandi escarpment, 5,800 ft., 29.v.1911 (*S. A. Neave*), 4 specimens.

Allied to *P. maculiceps*, Bryant, from Kenya, but differs in the entirely black head, and the puncturation of the elytral striae not nearly so close.

Podagrica coerulea, sp. n.

Oblong, ovate, slightly convex, upper surface deep metallic blue, underside and legs black, antennae with the four basal segments tinged with fulvous, prothorax very finely and not closely punctured, elytra with the punctures forming double longitudinal rows. Length 4–4·5 mm.

Head deep metallic blue, feebly punctured on the vertex, a transverse impression between the eyes. *Antennae* not extending to the middle of the elytra, the four basal segments tinged with fulvous, the remainder black and pubescent, the basal segment longer and more dilated than the second, the third long and slender, the fourth shorter and about equal to each to the tenth, the eleventh longer and acuminate. *Prothorax* deep metallic blue, very finely but not closely punctured, very transverse, the sides slightly rounded and contracted in front, the anterior angles not prominent, a deep short longitudinal impression on the anterior margin near the angles. *Scutellum* deep metallic blue, sub-triangular, impunctate. *Elytra* oblong, slightly tapering from the middle of the apex, deep metallic blue, the punctures forming double longitudinal rows, the intervals smooth and nitid. *Legs* black, the apical portion of the femora tinged with fulvous. *Underside* black, nitid, and rather strongly punctured, the ventral segments of the abdomen two to four about equal.

UGANDA: North-West shores of Victoria Nyanza, 3,800–3,900 ft., 12.ix.1911 (*S. A. Neave*), 6 specimens; shores of Lake Isolt, nr. Wamela, 3,800 ft., 7–8.i.1912 (*S. A. Neave*), 2 specimens; Bugoma, ix.1932 (*T. Jackson*), 1 specimen; Bugomolo, 24.iv.1927 (*H. Hargreaves*), 2 specimens.

Allied to *P. pallidipes*, Bryant, but differs in its entirely dark blue colour, black legs and slightly larger size.

Podagrica turneri, sp. n.

Broadly ovate, convex, head and prothorax rufous, the five basal segments of the antennae and legs fulvous, elytra black, narrowly margined at the sides with rufous, prothorax very minutely punctured, and the elytra with very fine double longitudinal punctures. Length: 4·5–5 mm.

Head rufous, the mandibles with the apical half black, impressed and rugose between the base of the antennae, the basal portion of the head impunctate. *Antennae* rather short, extending slightly beyond the base of the elytra, the five basal segments fulvous, the remainder black and pubescent, the basal segment the longest and more dilated, the second shorter than the first and third, the fourth shorter than the third, and about equal to each to the tenth, the eleventh slightly longer and pointed at the apex. *Prothorax* rufous, very transverse, widest at its base, sides rounded and contracted in front, a strong short longitudinal impression on the anterior margin near the anterior angles, the surface very finely punctured. *Scutellum* rufous, rounded at the apex and impunctate. *Elytra* black with the side margins narrowly rufous, broadly rounded, widest at the middle and then gradually rounded to the apex, very finely punctured in double longitudinal rows, the punctures slightly stronger than on the prothorax. *Legs* fulvous. *Underside* black.

KENYA: Lower Tana, Sabaki, iv-v.1932 (*Turner, McArthur*), 4 specimens.

A large and conspicuous species on account of its more rounded appearance and dark coloration.

Podagrica viridipennis, sp. n.

Ovate, head, prothorax, base of antennae and anterior pair of legs rufous, elytra metallic green, the posterior femora fuscous, head and prothorax very finely and the elytra with the puncturation slightly stronger. Length : 3 mm.

Head rufous, very finely and not closely punctured, feebly carinate between the insertion of the antennae, the palpi tinged with fuscous. *Antennae* extending slightly beyond the base of the elytra, the five basal segments rufous, the remainder black and pubescent, the basal segment longer and more dilated than the second, the third more slender and slightly longer than the second, the third to the tenth about equal to each other, the eleventh slightly longer with the apex pointed. *Prothorax* rufous, transverse, the sides rounded and feebly margined, the anterior angles acute, very finely and closely punctured, a short longitudinal impression on the anterior margin at each side near the angle. *Scutellum* fuscous, impunctate, rounded at the apex. *Elytra* metallic green, the sides almost straight and rounded at the apex, finely punctured in irregular double longitudinal rows, the punctures stronger than on the prothorax. *Legs* with the anterior and middle pair rufous, the posterior pair with the femora and tibiae fuscous, the tarsi rufous. *Underside* with the ventral segments of the abdomen black, feebly punctured and with scattered pubescence, the segments two to four the shortest, and about equal to each other.

KENYA : Kaimosi, iii–iv.1932 (*A. Turner*) 7 specimens ; Kakumega, Yala River (*A. Turner*) 2 specimens.

Allied to *P. dilecta*, Dalm., but differs in the bright green elytra and the puncturation.

Podagrica marshalli, sp. n.

Broadly ovate the head and prothorax fulvous, elytra dull blue, antennae and the five basal segments fulvous, the remainder black, legs fuscous, underside with the prosternum fulvous, the remainder fuscous. Length : 3 mm.

Head fulvous, very finely and not closely punctured, the labrum and palpi fuscous. *Antennae* extending slightly beyond the base of the elytra, the five basal segments fulvous, the remainder black and pubescent, the first segment the longest and nitid, the second a third shorter than the first, and about equal to the third, the six terminal segments slightly thickened. *Prothorax* fulvous, very transverse, widest just before the middle, the sides rounded in front and slightly contracted behind the middle to the base, the surface very finely and not closely punctured, the anterior margin with a deep short longitudinal impression at either side near the anterior angle. *Scutellum* blue black, impunctate, the apex rounded. *Elytra* dull blue, widest before the middle, rounded at the shoulders, tapering and rounded at the apex, more strongly punctured than the prothorax, the punctures forming irregular double rows. *Legs* fuscous, tinged with fulvous, the male with the basal segment of the anterior tarsi more dilated, and slightly smaller than the female. *Underside* with the prosternum fulvous, the rest fuscous, the first ventral segment of the abdomen the longest, each segment with a few strong punctures.

PORTUGUESE E. AFRICA : Beira, iv.1902 (*Sir G. A. K. Marshall*), 10 specimens.

This is a very distinct species, on account of its broad and flattened appearance, which is more marked than in the other blue and fulvous species, more related to *P. turneri*, Bryant.

THE UTILISATION OF WASTE LUBRICATING OIL IN MOSQUITO LARVICIDES.

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Introduction.

From time to time the possibility of using waste lubricating oil in larvicides has attracted attention (*e.g.*, Peterson & Ginsburg, 1929), but usually under peace-time conditions the collection of the relatively small batches has not seemed worth while. The war, however, makes available large quantities of waste oil in a comparatively few centres, *e.g.*, aerodromes, where the disposal of the material presents quite a problem. It is therefore of interest to enquire into the exact potentialities of these waste oils as ingredients for larvicides.

During the course of this work, nine samples of waste lubricating oils, obtained from various Army and R.A.F. depots, have been examined, and it has been found possible to blend all of them into serviceable larvicides. The results obtained with such blends are inferior to those which would be acceptable in a specially blended

TABLE I.

Description of sample.	Redwood I Viscosity at 70°F. Sec.	Spreading pressure dynes/cm.
Kerosene : Pladjoe Power Kerosene ...	—	Less than 16
Diesel Oil : Balik Papan	45	16
Waste Oil I : Very black : much sediment ...	2,160	Better than 16
Waste Oil II : Very black : much sediment ...	480	,, ,,
Waste Oil III : Very black : much sediment ...	360	16
Waste Oil IV : Black : some sediment	400	16
Waste Oil V : Red brown : filtered	1,260	Less than 16
Waste Oil VI : Black : much sediment	1,470	Better than 16
Waste Oil VII : Black : only a little sediment ...	1,560	,, ,,
Waste Oil VIII : Black : some sediment	2,520	16
Waste Oil IX : Black : much sediment ...	705	16

larvicide (*cf.* David, 1942) as will be seen from the data quoted later, but it is also quite apparent that adequate control of larvae can be obtained by means of blends incorporating up to 30–35 per cent. volume of waste lubricating oil, the remainder of the mixture being Diesel oil and kerosene. Obviously such a blend represents an attractive saving of petroleum products and may make possible the continuation of regular oiling treatments which would otherwise have to be abandoned under the stress of war.

In a previous paper (David, 1942), methods of testing and blending larvicides and their constituents have been fully described. As a preliminary to the present work, the nine samples of waste lubricating oil and the kerosene and Diesel oil also incorporated in the blends were tested, in accordance with the procedure described. The results obtained are set out in Table I.

From the table it will be seen that the viscosity of the waste oil samples varied considerably—from 360 to 2,520 sec.—no doubt in part due to the different grades of oil originally used but also probably because the less viscous samples contained a larger quantity of motor fuel heavy ends which pass into the crank case and dilute the lubricant. In some instances the variation in viscosity may be due to contamination of the waste oil with lighter fractions used to rinse out the crank cases when the oil was changed. It would have been interesting to test this point but the size of the sample made it impossible.

With the exception of Sample No. V, all the oils were in the condition in which they were drained from the engine sumps. They were all black, due to suspended particles of carbonaceous and other matter and most of them contained a sediment of heavier particles and some water. The one sample which had been filtered (No. V) was not free from carbonaceous particles and was also " blind " owing to moisture. Only this sample had a spreading pressure below 16 dynes cm.

Before the waste oils are made up into larvicides, it would probably be necessary to remove the coarser particles which form the sediment, otherwise these might cause clogging of the spray nozzles. This could be simply achieved by decanting the oil from the coarser sediment and then straining it through a strainer of the type recommended by Peterson and Ginsburg. These workers used a simple type made up of two concentric cylinders of copper gauze. The inner cylinder had a diameter of 5 inches and consisted of 16 mesh gauze, while the outer cylinder was 6 inches in diameter and was made up with gauze of 30–40 mesh to the inch. When the oil is passed through such a strainer, the coarse materials are removed by the inner cylinder and the finer ones by the outer.

In the field one would not carry out the Redwood viscosity test on the waste oils, instead a blend of say 15 per cent. kerosene, 55 per cent. Diesel oil and 30 per cent. waste oil would be made up and tested, as described in the previous paper, for viscosity and spreading pressure.

It will be noted that this trial formula departs from that previously recommended : it does so in order to meet the special case of waste oils which are of low toxicity and of which it is desirable to utilise as much as possible in the finished larvicide.

Properties of the Waste Oil Blends.

The nine blends first prepared and tested did not differ sufficiently in any of properties to make a full presentation of the results worth while ; instead a selection only is given in Table II.

Owing to the shape of the viscosity curve obtained on mixing a viscous with a fluid oil, it is not necessary to alter the waste oil content of the blends more than 5 per cent. to bring the viscosity of the mixture near to the desired level, even when the viscosity of the waste oil varied from 360 sec., to 2,500 sec., as it does in the cases of oils III and VIII quoted.

TABLE II.

Blend No.	Composition—% Volume				Properties	
	Kerosene	Diesel oil	Waste oil	Vis. RI at 70°F. (sec.)	Spreading pressure	Film stability
1	10%	60%	30% III	54	16 app.	Very good
2	15%	60%	25% VI	55	+ 16	Good
3	15%	60%	25% VIII	59	16 app.	Very good

All the blends which were prepared had a spreading pressure of about 16 dynes cm. or more, so that they met the minimum requirements of the specification, but in certain cases waste oils may be encountered with lower spreading pressures and in the absence of a Diesel oil with a high spreading pressure to conteract this, difficulties may arise.

In various parts of the world, commercial preparations are available for increasing the spreading pressure of larvicides, but in the absence of these it is worth experimenting with the addition of up to 1 per cent. of cresylic acid or the same amount of crude castor oil. As a further possibility, any locally available vegetable oil at the same dosage might be tried, but the few experiments made with crude palm oil, ground nut oil and coconut oil were not encouraging. All samples tested except crude rape oil brought the spreading pressure up to a satisfactory level, but induced film instability to varying extents. Sometimes the films broke up immediately, while in other cases they remained stable until disturbed by gentle stirring when they broke up into numerous droplets which did not reunite on standing. Undoped mineral oil films did not have these objectionable properties. Similar behaviour is reported by Murray, 1938.

Effectiveness of the Blends against Culicine Larvae.

The question of the lethal effect on the larvae is omitted from the above table since it is sufficiently important to demand separate consideration. When the larvicides were tested in the shade as described in the previous paper, using 0·5 c.c. oil on a bowl 30 cms. in diameter (equivalent to 2·2 fluid oz. per 100 sq. ft.), the kills of *Aëdes aegypti* larvae were definitely unsatisfactory when compared with those obtained with an approved commercial larvicide. Microscopic examination of the larvae showed that this was due to the failure of the oil to enter the tracheae. At first this was thought to be due to the carbonaceous materials in suspension in the waste oils clogging the spiracles (the waste oils were always shaken so as to include the sediment before blending and the blended larvicide was also shaken before testing) and so preventing adequate oiling. In order to test this point the blends were shaken with Fuller's earth, filtered and re-tested. This resulted in a striking improvement in the number of larvae oiled, and a different behaviour of the larvae under the film. Under the untreated film no larvae were stuck in the oil at the end of 30 min., whereas with the treated larvicide some of the larvae were always stuck in the film at the end of this period. The explanation of this difference and the increased efficiency of oiling was found to be that earth treatment and filtering reduced the spreading pressure of the oil well below 16 dynes/cm., *i.e.* it became less hydrophilic and consequently able to " wet " the larva more readily. When the larva stuck in the oil film, it soon became oiled. When the original waste oil alone was earth-treated and blended with untreated kerosene and Diesel oil, the spreading pressure of the blend was intermediate between that of the untreated and treated blend and the effectiveness of oiling was also intermediate between the two. Mere filtration of the larvicide without earth-treatment only removed the carbonaceous matter without altering the spreading pressure and did not increase the readiness with which oiling was achieved (Table III). Since earth-treatment reduces the spreading pressure of the larvicide it is of no practical importance.

TABLE III.

Blend No.	Percentage of larvae oiled			
	Original blend	Filtered blend	Blend made from the treated and filtered waste oil	Earth treated and filtered blend
1	8	9	40	67
2	5	8	33	60
3	25	—	—	62
4	8	—	—	50

Two possibilities remained, one of using a thicker film of oil and the other of reducing the percentage of waste oil in the blend and so, by reducing the viscosity, facilitating oiling. The second alternative will be considered later. When the thickness of the oil film is doubled, *i.e.* the dose becomes 1 c.c. on a bowl 30 cm. in diameter, equivalent to 4·4 fl. oz. 100 sq. ft. (which is still well within the dosage commonly applied in the field), the results obtained were entirely satisfactory.

TABLE IV.

Effect of Doubling the Film Thickness on Number of Larvae Oiled.

Blend No.	Single thickness 2·2 fl. oz./100 sq. ft.	Double thickness 4·4 fl. oz./100 sq. ft.
1	8	90
2	10	95
3	29	100

Effectiveness of Blends against Anopheline Larvae.

Beside the above tests with *Aëdes*, *Anopheles maculipennis* larvae were tested. It is well known that Anopheline larvae are much more readily oiled (*cf*. Green, 1924) than Culicines and, as was expected, the waste oil blends killed *Anopheles* efficiently at the lower dosage. When the larvae had been exposed under the film for 30 mins. about 70–100 per cent. were dead at the end of 24 hours.

Beside the above tests, it seemed worth while determining the maximum amount of waste oil which could be incorporated in a larvicide if good results were to be obtained in comparison with an approved commercial larvicide. Waste oils III and VIII were again chosen as representing the extreme viscosity limits and the following blends made up :—

TABLE V.

Blend No.	Composition—% Volume				Properties		
	Kerosene	Diesel oil	Waste oil	Vis. RI at 70 (sec.)	Spreading pressure	Film stability	Toxicity % kill
1	10	60	30 III	54	16	Good	16
5	15	75	10 VIII	44	16	Good	93
6	15	70	15 III	45	16	Good	82
7	20	65	15 VIII	48	16	Good	57
8	20	60	20 III	44	16	Good	60
Commercial Sample	?	?	—	37	+16	Good	60

The above Table V indicates that if only a small percentage of waste oil is incorporated in the blend or a larger percentage of kerosene is used, the results obtained in the laboratory compare favourably with those given by a commercial larvicide at the same dosage.

Conclusion.

As usual with discussions on larvicides, no set formula can be laid down for the blends containing waste lubricating oils : each sample of waste oil must be tested individually and trial blends made up. Whenever possible, a few small scale field trials should be made if there seems to be any doubt concerning the best formula or the optimum dosage. Such trials could obviously have been included in the present work with advantage but it was not possible to make them.

It should be recognised that waste lubricating oils are chemically and physically unsuited for ingredients of larvicides, and it is only considerations of economy and availability which make them of interest for this purpose. For the best results therefore it is more than usually necessary to choose kerosene and Diesel oil of high toxicity and spreading pressure. This was not done in this work, since it was considered undesirable to investigate an ideal case and so set a standard for the kerosene and Diesel which would not be commonly met in the field. Having this fact in mind the results recorded are all the more interesting.

Acknowledgments.

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Summary.

Nine samples of waste oils have been examined and after blending with kerosene and Diesel oil their suitability as larvicides was determined. It is concluded that blends containing 25–30 per cent. of waste oil are not so effective as an approved commercial larvicide at the same dosage but that with a higher dosage, which is still within the range commonly applied in the field, *i.e.* between 4 fl. oz. and 6·7 fl. oz.

per 100 sq. ft. (Ramsay & Carpenter, 1932) they give good results. The higher dosage is only necessary when Culicine larvae have to be controlled. Other blends containing 10–20 per cent. of waste oil are just as effective as an approved commercial sample.

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SOME RESULTS OF STUDIES ON THE DESERT LOCUST (*SCHISTOCERCA GREGARIA*, FORSK.) IN INDIA.

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[A voluminous general report on the organisation and the results of the locust investigations carried out in India in 1931–1938, under the auspices of the Imperial Council of Agricultural Research, was officially submitted to the Council by Rao Bahadur Y. Ramchandra Rao in 1941, but its publication has been postponed until after the war.

A copy of the report has been sent, by permission of the Council, to the Anti-Locust Research Centre at the Imperial Institute of Entomology, for information, and it proved to contain a wealth of data and of ideas, only some of which have been published in various preliminary papers by its author and by his colleagues. In view of the great scientific and practical value of the report, it appeared necessary to make at least its main findings available to other entomologists working on the subject, and permission has been obtained from the author and from the Imperial Council of Agricultural Research for the publication of some sections of the report. Only a few sections, selected and edited by Dr. B. P. Uvarov, are being published below, and it should be stressed that their publication in the abridged form does not in any way detract from the value of the complete report, which, it is hoped, will be published at the earliest opportunity for the benefit of all workers on the locust problem.]

Studies on the Development.

Maximum Number of successive Generations possible in a Year.

Husain and Ahmad (1936) have proved that there is no diapause in the Desert Locust, *Schistocerca gregaria*, Forsk., in any stage of its development and that as many as eight successive generations may be obtained within a year at a constant temperature of 40°C., about seven generations at 36°C., and five at 30°C. Under natural conditions, however, there is always a considerable fluctuation of temperatures, diurnal as well as seasonal, so that the duration of a brood would naturally vary in accordance with the prevailing temperatures. In nature, the main factor in the breeding of the locust would appear to be the presence of an optimum amount of moisture in the soil. This, under natural conditions, is dependent on requisite rainfall, and as apparently the mass-multiplication of the locust depends on optimum conditions of rainfall, it was considered desirable to measure the potentialities of increase possessed by the insect by rearing it under confinement in cages in the actual desert environment, but providing it with the optimum amount of soil-moisture. Pairs of locusts kept in cages and provided with fresh food and with wet sand at the bottom were found breeding satisfactorily and producing a succession of generations, although in nature in the neighbouring breeding grounds, only a single generation was observable.

The results of breeding permit the following deductions to be made :—

1. During late spring and in summer, when the average monthly mean temperatures vary from 28 to 30°C., the periods of sex maturation, egg incubation and hopper development are shortest, but in spring and autumn, when the means range from about 22 to 26°C., they tend to be much longer, and in winter development is

extremely slow. In summer, sex maturation may occur in 3 to 4 weeks, eggs may hatch in about 14 days and hopper development may be completed in about 31 days.

2. In mid-summer, the life-cycle, from oviposition by the parent generation to egg-laying by the progeny, may be completed in about two months and a half, but since it is much longer in spring, autumn and winter, it is not possible to have more than three successive generations during the year. At Pasni the total time taken for the four successive broods was about 14 months. At the utmost, one might have seven generations in the course of two years.

3. At Pasni, there is usually only one brood in the year in the spring months, and as summer is a period of drought, there is no breeding then. On the other hand, Ambagh and Chachro fall within the zone of summer rainfall and breeding occurs only in summer, and there is no breeding in winter and spring, which are periods of drought. Usually, locusts tend to leave areas of drought and migrate elsewhere. However, whenever there is good rainfall in summer at Pasni breeding may take place there. Moreover, in years of heavy rainfall, young hoppers were being met with at Pasni in certain special areas from June to September, although none were noticed on the general *rek* (sand dune) areas after May. On investigation, this was found to be due to egg-laying in wet patches of sand laid bare by the heavy south-west wind. This would indicate that breeding may, under these special conditions, continue in these areas in spite of the absence of rainfall. Similarly at Ambagh, light breeding was noted in spring in 1939 as a result of exceptionally heavy rainfall, though usually no breeding occurs there in spring.

4. Although there is usually little possibility of there being more than a single generation at places like Pasni and Ambagh in an ordinary year, the powers of migration possessed by locusts enable them to reach places where they may be able to lay eggs immediately. New adults emerging in April on the coastal *reks* may reach the interior valleys of Mekran and start a new brood in May, and adults of this new generation appearing by the end of June, may migrate to the Rajputana desert in July and may lay eggs during the month. Adults of this generation appearing in September may, under favourable circumstances, start a new brood by the end of the month. Theoretically, therefore, there is the possibility of four successive generations following one another in the course of the year, though ordinarily not more than three broods can be expected.

The Length of the Incubation Period under semi-natural Conditions correlated with Soil Temperature.

Eggs are deposited in fairly soft sandy or loamy soils, generally at a depth of about 4 inches, and their development is dependent on the existence of optimum conditions of soil-moisture and soil temperature at that depth. Under natural conditions in the desert, the requisite moisture conditions are obtainable only for 3 to 4 weeks after good rainfall, and usually the locust lays its eggs only when the soil-moisture conditions are satisfactory. On the other hand, conditions of soil temperature are affected not only by the diurnal and seasonal fluctuations of atmospheric temperatures, but also by the intensity of solar radiation.

In the course of breeding experiments undertaken at Pasni, the actual times of egg-laying and hatching were noted in a large number of cases and correlated with the average mean temperature of moist sandy soil at 4-inch depth observed in cages during the development. Although the correlations cannot be claimed to be accurate, the results (Table I) may give an approximate idea of the length of the incubation period that may be expected under particular types of seasonal conditions in nature.

TABLE I.

Incubation Period in relation to Soil Temperature at 4 in. Depth, showing the Difference in Values for each Rise of a Degree Centigrade. Compiled from Data for the Years 1932 to 1937.

No. of records	Soil temperature of moist sand at 4 in. depth °C	Incubation period in days.	
		Individual records	Averages
2	19	73, 70	71·5
1	20	48	48
1	21	37	37
6	22	37, 36, 34, 36, 32, 29	34
3	23	28, 29, 29·5	28·8
7	24	27, 27, 26, 29·5, 27, 25, 27	26·9
3	25	25, 24, 25	24·7
11	26	25, 25, 24, 22, 26, 26, 25, 22, 23, 28, 25	24·6
19	27	23, 20, 21, 23, 21, 20, 23, 25, 22, 23, 24, 24, 21, 24, 20, 21, 20, 20, 20	21·8
9	28	18, 19, 22, 22, 19, 19, 19, 18, 19	19·4
11	29	20, 19, 19, 16, 17, 18, 17, 18, 19, 18, 19	18·2
12	30	16·5 14·5, 14, 17, 17, 17, 17, 16, 17, 17, 17, 16	16·3
24	31	16, 15·5, 15, 14, 16, 16, 13, 16, 15, 18, 15, 16, 16, 17, 16, 14, 17, 16, 14, 15, 14, 15, 14, 15	15·4
13	32	15, 15, 15, 16, 13, 15, 15, 14, 15, 15, 15, 14, 14	14·7
14	33	16, 15, 14, 14, 16, 14, 14, 12, 14, 15, 15, 14, 14, 15	14·4
1	34	13	13

The Length of the post-embryonic Period under semi-natural Conditions, correlated with average atmospheric Temperatures.

Table II shows the correlation between the average daily mean temperature and the length of the hopper period.

The results show that the shortest period recorded is 32 days at an average mean of 31°C., while at an average of 20°C., the duration is as high as 85 days.

Food and Sexual Maturation.

Bodenheimer (1932) made the suggestion that fresh succulent vegetation growing after rainfall may exert a powerful influence in quickening the sex maturation of locusts. In order to test this, Dr. K. R. Karandikar confined pairs of locusts of known age in oviposition cages and fed them on fresh shoots of marrand (*Heliotropium undulatum*). Although the sand at the bottom of the cages had been kept quite dry, the locusts attained maturity in about two months and dropped their eggs on the surface of dry sand. At that season, there was no fresh marrand anywhere on the Pasni *reks* on account of the drought nor were any mature locusts met with in the area.

TABLE II.

The Correlation between the Length of the post-embryonic Period and mean atmospheric Temperature. Compiled from Data of 1933–1935.

Temperature °C	Minimum duration of post-embryonic development (in days)			
	1933	1934	1935	Averages
20°	—	85	—	85
21°	83	—	—	83
22°	—	—	—	—
23°	—	54	—	54
24°	44	54	—	49
25°	41, 40	—	43, 42, 39, 37	40
26°	35, 36	—	36	36
27°	34, 36	39	—	36
28°	—	—	37	37
29°	—	—	38	38
30°	34	36, 34, 34	—	34
31°	32	—	—	32

TABLE III.

Effects of Food on sexual Maturation.

Plant	Yellowing of wings in days	First oviposition in days	Number of egg-pods
Heliotropium undulatum, fresh	13–25	33–79	2–4·4
Ditto, old	17–25	43–90	0–3
Jowari (*Sorghum*)	13–36	28–72	2–5
Ditto, seedlings	7–20	25–37	3–5·3
Maize	13–16	34–64	1·7–3·7
Sericostoma pauciflorum, fresh	12–25	33–76	1–4
Ditto, old	13–16	39–67	1–3
Aerua tomentosa	15–41	37–104	0–4
Cyperus arenarius	21–68	38–100	0–2
Mixed plants	21	57	1·8
Cabbage	8	24	6
Indigofera cordifolia ...	17	37	1
Tribulus terrestris	11	36	2

On the basis of these results, further experiments were undertaken. These experiments included (1) the use of fresh shoots of marrand as against shoots of old or semi-dry marrand, (2) old marrand shoots wetted to counter-balance the deficiency of water-content, (3) old marrand kept in a moist atmosphere, and (4) fresh shoots of other food-plants. Subsequent experiments were restricted to comparative tests of fresh and old marrand, of fresh and old kharzan (*Sericostoma pauciflorum*) and to tests of other important food-plants. In all these experiments, the appearance of the yellow tinge of the hind wings has been taken as the first landmark in sex maturation, though the final criterion, of course, would be the date of first oviposition.

The results given in Table III are averages, and the differences do not, for that reason, appear in many cases to be very striking, but they are markedly significant, *e.g.*, in the case of short duration of sex maturation on sorghum, maize and cabbage.

The circumstance that cereal crops like sorghum and maize have been found to hasten the sex maturation of adult locusts is of significance owing to the fact that in all known cases of outbreak centres found in the various parts of Mekran and Lasbela, sorghum crops are associated with their formation. Not only have the hoppers been found on and among such crops, but adult locusts have been observed concentrating in them for feeding and resting. Similarly, in the Sind-Rajputana desert areas, where bajri (*Pennisetum typhoideum*) is the chief cereal crop, hoppers as well as adult locusts have been found congregating among the crops. In the absence of cultivation, wild plants like marrand, kharzan, *Indigofera cordifolia* and *Tribulus*, all of which are preferred food-plants, proved by these experiments to have a stimulating effect on the maturation of the locust, may similarly induce outbreak centres to form in those places where they occur in masses.

Food and the Rapidity of Growth of Hoppers.

Freshly hatched hoppers were reared individually and in batches on different wild and cultivated food-plants.

The results showed that the food-plants experimented with may be placed in the following order in regard to their effect on the developmental period of hoppers during the hotter months :

Kolhrabi cabbage (31 days) ; sorghum seedlings (35·9) ; *Indigofera cordifolia* (36) ; *Tribulus terrestris* (37) ; *Convolvulus pleuricollis* (38·7) ; fresh *Heliotropium undulatum* (40) ; fresh *Sericostoma pauciflorum* (40) ; maize seedlings (44) ; *Crotalaria burhia* (44·5) ; *Aerua javanica* (45·6).

General Observations on Food and Development.

Although the experiments carried out were not exhaustive, they have given fairly definite indications as to the importance of the quality of food in causing an acceleration of the sexual maturation of young adults and of the growth of the hoppers. Since it is now generally conceded that the development of an outbreak centre is almost always due to the rapid development of two generations in quick succession, any factor that might contribute to the speeding up of the breeding would be of the utmost importance in this connection, and there is little doubt that the presence of food-plants capable of stimulating the rapid growth of hoppers and of hastening the maturity of young adults would play an important part in the causation of incipient swarming.

Kennedy (1939) was not inclined to allocate to the food factor anything but a subsidiary rôle. While conceding that growth-stimulating foods such as *Heliotropium undulatum* might accelerate " Real Concentration," since the more mobile later instars would thereby be reached sooner, and also that growth stimulation might assist in " Virtual Concentration " as a result of rapid breeding, he believed that this would only contribute to the fitting in of a second generation into a winter season. He further said (p. 444) that the effect of food on the rate of sexual maturation can only influence prospects of a second winter generation and hence of " Virtual Concentration," but would have no influence on concentration of the first winter generation.

In the Mekran area of the Indian region, where spring breeding usually occurs, locusts are found over-wintering in the coastal areas and the earliest breeding also occurs there. As the spring advances, locusts migrate into the interior valleys of Mekran from the coast and may breed there if conditions are favourable during the months of April, May and June. Adults of the new generation begin to appear on the coastal areas early in April and usually migrate into the hinterland more or less immediately. As the interior of Mekran is mostly hilly and stony and patches of natural vegetation as well as of cultivation are restricted to loamy soils at the bottom of the valleys, migrating locusts usually become concentrated on such patches (Real Concentration). Summer cultivation there is mostly confined to the sorghum crop, and various wild plants, such as species of *Astragalus*, *Trigonella*, *Tephrosia*, *Tribulus*, *Chrozophora* and *Heliotropium*, as well as the Camel-thorn, *Alhagi camelorum*, all of which are plants relished by locust adults and hoppers, are generally commonly found near cultivation. Locusts concentrated on the sorghum crop may be expected to attain sexual maturity very early and to lay eggs in the neighbourhood, and the hoppers on hatching would find a fair amount of growth-stimulating food. As temperatures in the late spring are fairly high, breeding would be rapid and conditions should apparently be quite favourable for the development of incipient swarms. Although no actual observations have been made on this point, several outbreak centres are known to have developed under such conditions in the interior of Mekran.

As to the adults of the over-wintered brood, it is now fairly well established that the locusts found in the winter months in the Mekran coastal areas are mostly migrants from summer brood areas in the Sind-Rajputana desert. On the coastal *reks* the vegetation is generally very much dried up at the end of autumn, but with the setting in of the moist western winds at the end of autumn, most of the perennial vegetation on the *reks*, such as *Heliotropium undulatum* and *Sphaerocoma aucheri* put forth fresh shoots in spite of the absence of rainfall, and tender shoots may be expected to stimulate sexual maturation even before the occurrence of the winter rains. On the other hand, with the commencement of rainfall, various annuals spring up on the *reks* and furnish food capable of quickening sex maturity among the over-wintered adults, though there is not much likelihood of any concentration being caused under the conditions prevalent at this period on the coastal areas.

In addition to the natural vegetation, young crops, such as wheat, barley and rape, raised in parts of Mekran would also provide food capable of stimulating maturity, in case locusts happen to be present in the neighbourhood.

Effect of Sunlight on the Coloration of Wings.

In recently fledged adult locusts, the hind-wings are always hyaline. In cold weather there may be no development of colour for a long time, but in summer a tinge of yellow usually makes its appearance within a week, signifying the onset of sex maturation and the deepening of yellow colour is a positive indication that the insect is mature.

In many specimens of locusts collected from nature, the occurrence of pink or mauve or light blue colour at the base of the wings was often noticed. During the earlier years of the locust survey work the significance of this coloration was not recognised. It was not till the year 1935, when definite proof of the migration of solitaires was first obtained, that the significance of the possession of distinct mauve or pink patches on the wings in connection with migration was first noted. Observations repeated during the summer and autumn migrations of 1936 and 1937 clearly showed that such a pink or mauve tinge in the wings was decidedly connected with active migration flight, being presumably the effect of the action of solar radiation on the wings, while exposed to the sun during flight. With the object of obtaining a confirmation of this conjecture, some experiments were devised.

A cage was set up in which some recently transformed locusts were introduced after having one, or both, elytra removed. The cage was kept in the open, fully exposed to the sun, which was very bright and hot. In the course of a week or two, wings exposed to the sun had in all cases acquired a pink colour, which subsequently gradually deepened into mauve. In the case of specimens, in which only the right elytra had been removed, it was noticed that pink or mauve had appeared even in the left wing, although the colour was less intense.

In other experiments, Mr. R. N. Batra removed the right elytron and painted the other elytron black so as to prevent the sun's rays from infiltrating to the wing beneath, and found no trace of pink or mauve developing on them even at the end of a month, though there was colour development as usual on the exposed wing. When he painted both elytra black, the development of mauve or pink had been completely eliminated. When locusts, with the right forewings removed, with both elytra removed and with both elytra intact, were kept in boxes completely shut off from sunlight neither pink nor mauve made its appearance, though the yellow tinge characteristic of the onset of sex-maturity developed in due course.

These experiments indicate that the appearance of light mauve or pink in wings, even in those cases where the forewings had not been removed, should have been due to the infiltration of sunlight through the forewings.

On the whole, the experiments have fairly clearly proved that the development of pink, mauve or light blue at the base of the hind-wings is the result of exposure to sunlight. In nature, there is a great amount of variation in the type of colour, as well as in the depth of the tinge. Pink is common in the gregarious forms, and in 1935 many of the immigrants showed a pink colour not only on the hind-wings but also on their bodies. On the other hand, mauve is very common among the autumn migrants found in the Lasbela and Mekran areas during the months October to December. In some cases there is only a very light pale bluish suffusion at the base of the wing, and in others the mauve is well developed. In certain cases only the veins acquire a dark bluish colour, while there is no colour at the base. All these differences are probably due to the degree to which the wings have been exposed to sunlight during flight. In the summer months it is probable that migration takes place in the evening or early part of the night, while in the autumn months and in winter the nights are cold and movements probably occur during midday or early afternoon. In the latter case there are greater chances of exposure to sunlight, and at this time, moreover, locusts love to bask in the sun, hence the deep mauve of the wing-bases and also the darker body colour. Since pink is associated to a greater extent with the *gregaria* forms and mauve tinge with the *solitaria* individuals, an investigation into the physiology of these colour developments may throw much light on their relationship with phase.

Biometrical Studies.

Biometrical Ratios.

The ratio E/F (elytron length over hind femur length) was the one almost exclusively adopted for studying the populations found in different areas. In view of the frequent cases where the tips of the elytra were broken, it was necessary to evolve a method of estimating their length. After various tests, the point where the anal (or vannal) area ends on the posterior margin of the elytron was found the most suitable for determining the position of the specimen on the E/F scale, since the length of the elytron up to the tip of the anal area was found to bear a definite relation to the length of the entire fore-wing. It is proposed to call this point the " Vannal Apex " or " Vannal Tip," and the new ratio, which is determined in exactly the same manner as the E/F ratio, the V/F ratio.

Since the E/F and the V/F ratios are both based on the length of femur (F), the relationship between the two ratios is the function of E/V. By numerous measurements it was found that the function varies between 1·30 to 1·33 on the whole, and in the majority of cases it is between 1·31 and 1·32. If the V/F ratio is determined, E/F ratio would probably lie between V/F × 1·31 and V/F × 1·32.

In the course of making measurements of the various parts of the locust for the determination of the pronotal ratios, it was apparent that the width of the head was a fairly significant point for examination. A comparison of the heads of specimens of the phases *solitaria* and *gregaria* showed that while there were clear differences in width at the genal region of the face, there were none in the region of the compound eyes. Comparing the facial contours of *solitaria* and *gregaria*, a distinct bulge is seen in the cheeks of the latter, whereas the ocular outline is not dissimilar. In the course of biometrical measurements, a new ratio —C/O, showing the relation between the maximum width of the face at the genal region (C) and the maximum width at the ocular region (O), was worked out along with the other ratios. (See Table IV.)

TABLE IV.

Biometrical Ratios in different Phases.

Ratio	*solitaria*	*transiens*	*gregaria*
E/F	1·88–2·05	2·06–2·15	2·16–2·34
P/C	1·617–1·430	1·462–1·315	1·387–1·243
M/C	0·888–0·757	0·887–0·722	0·805–0·705
H/C	1·258–1·666	1·224–1·071	1·187–1·040
C/O	1·02–1·08	1·03–1·07	1·17–1·20

The general results of a biometrical examination of the mass of collections gathered in the course of locust surveys indicate that the whole material falls into a long series of forms showing a great variation of characters, with extreme *solitaria* and *gregaria* at either end, connected by an infinite gradation of intermediate forms. The Desert Locust, as a species, may be likened to a mass of plastic material, which yields to the moulding action of its environment in varying degrees and in different ways. In the extreme *gregaria*, sharp differences are noticeable from the *solitaria* forms, in various characters such as longer elytra, shorter femora, a bulge in the cheeks, a depression in the crest of the pronotum, a shortening of the prozona and a constriction in the prothorax. In the intermediate forms, changes may be manifested in only one or two of these characters, and the transition from the *solitaria* to the *gregaria* does not occur as a continuous gradation involving all the characters. Variations in the different characters do not appear to be linked together, but occur independently. A locust having a particular E/F ratio need not necessarily be in the same state of development from the point of view of the other ratios, although an extreme *gregaria* or extreme *solitaria*, may exhibit typical development of all the various characters. Since E/F has proved to be the most expressive and significant ratio, changes in the phase characters have been shown in most cases in terms of this ratio in working out the biometrical facies of locust population in preference to the others.

Biometrical Facies of Locust Populations.

General observations made in the course of locust surveys carried out during the years 1931–38 have shown that locusts are being continuously affected by changes in the environment. There may occur as the result of local breeding and multiplication not only an increase in numbers, but also a change in the phase of the population, according to the conditions of the breeding. A similar change in the composition of the population may take place in the event of an immigration from outside. In estimating the character of locust populations, careful biometrical examination of sample collections is necessary. If the results indicate a predominantly *solitaria* facies, the inference would be that there is no immediate danger of swarming ; on the other hand, if there should be a fair proportion of *gregaria*, it may be taken as an indication of tendencies for forming concentrations that may lead to incipient swarming if the conditions are favourable.

In comparing different populations, average biometric ratios may be used, but they do not convey any idea of the extent of variation in regard to phase development in the population. In some cases, the extent of variation is of greater significance than the mean ratio. For instance, the presence of a small percentage of individuals with high *gregaria* ratio among an otherwise mainly *solitaria* population is of particular importance, but it would be obscured by merely quoting the average ratio. The phase variation within a population could be best expressed by tabulating the actual number of individuals in gradations of E/F ratios of the value of 0·05 as done by Zolotarevsky (1938). The frequency distribution of E/F ratios of similar value among the population can also be represented in graphs, as was done by Kennedy (1939). In both cases the range and the size of variation is clearly indicated.

In the present study, a different method of showing the constitution of field populations has been adopted. On the basis of a biometrical examination, the population is grouped under 3 categories : *solitaria*, *transiens* and *gregaria*, according to the individual E/F ratios, and it is also further grouped according to the number of eye-stripes possessed by the individuals, which may be either 6 or 7 (Ramachandra Rao and Gupta, 1939).

In regard to the phase characters, it has been found from an examination of specimens collected from flying swarms that the great majority possess E/F ratios 2·16–2·34. On the other hand, the great majority of the non-gregarious locusts have E/F ratios below 2·05, usually between 1·88–2·03. Though it is not possible to fix any rigid limit between the phases in nature, an arbitrary division has been made for the purpose of classifying locust populations, under the following 3 categories : (1) *solitaria* 2·05 and below ; (2) *transiens* 2·06 to 2·15 ; and (3) *gregaria* 2·16 and above (see Table IV). Murat (1939) in the course of a biometrical examination of *Schistocerca* in the Spanish Sahara, found that *gregaria* ratios ranged from 2·16 to 2·44 in females and from 2·17 to 2·28 in males, while his *solitaria* ratios ranged from 1·95 to 2·04. His results would appear to support our findings.

On the basis of the number of individuals found under (1) the phase groups of *solitaria* (S), *transiens* (T) and *gregaria* (G), and (2) under the eye-stripe groups, percentages are calculated, and the biometrical facies or index of the population is shown as percentage of individuals with different phase and eye-stripe characters in the following formula :—S : T : G : : (6) : (7). This method may be claimed to indicate at a glance the state of development of the population at any particular time or place from the view-point of phase, and has, moreover, been useful in identifying populations in different areas and in tracing the movements of non-gregarious locusts.

For example, the population found on the Mekran *reks* in January–March 1935 had the index :—76S : 23T : IG : : 34 (6) : 66 (7), whereas in April–May 1935, the index was :—62S : 29T : 9G : : 67(6) : 33(7). On the other hand, the facies of the locust population on the Mekran *reks* after the locust incursion in July was as follows :—24S : 35T : 41G : : 88(6) : 12(7). The decrease of the proportions of *solitaria* ratios and 7-stripes and the increase of *gregaria* and 6-stripes between January and July was striking and suggested an immigration from outside. Similarly, the facies of the immigrant population in the Sind-Rajputana desert in July 1935, was :—28S : 43T : 29G : : 92(6) : 8(7), which shows its affinities with the incursion population of Mekran. On the other hand, the index of the new brood found in October-November 1935 in the desert, was 69S : 30T : 1G : : 29(6) : 71(7), indicating a reversal to *solitaria* during the monsoon breeding in the desert. The population found in the Lasbela area in December 1935 had the index :—59S : 41T : OG. : : 64(6) : 36(7), suggesting an affinity between the desert brood and the autumn immigrants in the Lasbela area.

In working out the biometrical index, it is advisable to have as large a series of specimens as possible. In the course of the present studies, however, it has been found that even with as small a number as 20 or 25, fairly definite indications of the main characters of a population can be obtained.

Studies on the Distribution of the Solitary Phase.

Preliminary Surveys.

In 1930, at the time of the inauguration of the present scheme of Locust Research in India, there was no definite information available as to the source of the periodical infestations to which India has been subject. Although the generally accepted view was that the initial swarms reached India from a western direction, there was no positive evidence to indicate either that they had been derived from outbreak areas situated within Baluchistan, or that they merely formed a link in the chain of breeding areas connecting India with Arabia and Africa.

It was with the aim of detecting the presence of permanent or semi-permanent outbreak areas, if any, within Indian territory, that a special locust survey staff was appointed early in 1931, and stationed in Baluchistan (with Quetta as headquarters) in the first instance, as the province where such breeding grounds were most likely to be found. In the course of the year 1931, the survey staff examined the areas of Chagai, Lasbela, Mekran and Kharan between February and May. In September, a survey party traversed the desert areas of Kharan State. The Mekran and Lasbela coastal areas were revisited in September–October.

In the course of the following year, similar preliminary surveys were carried out in the rest of the desert or semi-desert areas of North-west India, *viz.*, Kachhi, western Sind, Lasbela, eastern Sind, Jhalawan, Kech and Kolwa, Loralai, the Dera Ghazi Khan and Bahawalpore areas of the Punjab, the Thar area of Sind, and various areas of the Rajputana desert. Surveys of Sirohi, Palanpur, Radhanpur and Cutch States carried out in the early months of 1933 completed the programme of surveys designed for obtaining a general knowledge of the distribution of the solitary phase locust within Indian limits. During the years 1932–1933, survey work was greatly facilitated by the provision of a one-and-a-half ton Ford motor-van, which was extensively used in carrying out most of the tours mentioned above. In all those places, however, where the motor-van could not be used, as in the interior of sandy deserts, journeys were performed on camels.

These extensive surveys amply served the purpose for which they were planned. The results obtained gave a general idea of the distribution of the *solitaria* locust population in the Indian area. It was, however, obvious that the records made in the course of these surveys had reference only to the conditions prevailing at the time, and that further surveys, repeated at different parts of the year, would be needed before any inferences in regard to their functioning as permanent reservations of the locust could be made. Moreover, in the course of survey work, a fluctuation of locust population was actually found to have occurred in certain instances.

Intensive Regional Surveys.

In the light of the experience thus gathered, it became evident that the type of surveys that were needed at this stage should be such as were calculated to supply information on the exact effect of seasonal changes on the behaviour and activities of the non-gregarious type of locust. Consequently survey tours of the extensive type were given up, and, from June 1933, survey work was restricted to the areas where solitary locusts were observed to be present, such as parts of Mekran, the Lasbela area and various areas of the Indian Desert. Since 1937, owing to the detection of very intensive breeding in Kachhi and in the hill valleys of Baluchistan, these areas were also subjected to regular periodical surveys. The areas of the habitat of the locust were divided into circles and sub-circles of convenient size, which were placed under the charge of Assistants and Fieldmen respectively for purposes of survey work. With the experience gained after a year of intensive surveys, a regular round of visits was plotted for each sub-circle and tours were arranged so that every area was visited once a month where possible (or at least once in two or three months, in particularly large or difficult areas) the staff being instructed to note down on the forms provided the number of locust adults or hoppers found, with particulars of the area covered, the condition of the environment and the state of activity of the insects.

By 1938 the survey comprised five circles, each subdivided in 2–5 subcircles, of which there were 14 altogether.

Intensive Local Surveys.

Though regional surveys of the type mentioned above have been of great value in giving a definite indication of the locust situation in the area concerned in different seasons, they could not give a continuous picture of the happenings at particular places. In the course of survey work, the data collected indicated not only that there was a fluctuation in the density of locust population at particular localities, but also that seasonal movements of the population were probably occurring. In order to obtain definite proof of such a phenomenon, intensive surveys were carried out in the neighbourhood of selected places throughout the year, commencing from 1934.

Such continuous records of locust activities have been obtained at the following stations :—

1. Pasni : as a centre for the western *reks*, in the region of winter rainfall (records from 1932).
2. Ambagh : as a centre for the eastern areas of the Mekran coast, subject to summer rainfall (from 1933).
3. Chachro : as a centre for the south-western parts of the Indian Desert (from 1934).
4. Sardarshahr : as a centre for the north-eastern parts of the Desert (from 1934).
5. Nokh : as a centre for the central parts of the Desert (from 1935).

Method of estimating Population Density.

In the earlier years of the present scheme, the number of locusts or hoppers observed or collected was noted down, as well as fairly detailed particulars of the areas examined. In certain cases, the surveyors gave rough estimates of the population density, according to their lights, but they were not exactly comparable.

It was not till 1935 that a general formula for working out the population density of locusts under Indian conditions was evolved. This formula has since been in use, with slight modifications, and has, on the whole, proved quite satisfactory.

In the course of the surveys, it has been observed that the solitary phase adults generally rest on the ground in open patches between bushes and in most cases sit basking in the sun. This is generally the case, while the sand surface temperatures range roughly between 80°–100°F. (about 25°–37°C.) When the soil temperature rises above 100°F. (37°C.), the locust either changes its place by flight or crawls into shade, usually under a bush, for shelter from the sun's rays. On the other hand, when the soil surface temperature falls below 80°F. (about 25°C.), the locust is not very active, and sits basking in the sun as long as possible and ultimately retires for the night at the base of a bush. Therefore it is only within the range of 80°–100°F. surface soil temperature that the best results can be obtained in survey work. During summer months, the optimum time would be between 8 a.m. and 11 a.m. and between 4 p.m. and 7 p.m., while in the winter months the best period would be between 10 a.m. and 3 p.m.

When locusts are most active, they are very sensitive to the approach of men and rise up abruptly from the ground or bush and fly out. Curiously enough, they do not seem to mind camels or cattle unless these approach very near to them. When, however, an observer walks along waving a stick right and left very few locusts will remain undetected, within the range of 10 to 12 feet on either side. A distance of 11 feet has been fixed rather arbitrarily, as it is convenient for purposes of calculating fractions of a mile. The distance travelled by an observer during a survey can be determined either by his carrying a pedometer, or roughly by other means. Supposing, for example, a man had walked three miles and had found 10 locusts, the area covered by him might be computed in square miles by multiplying 3 miles by 22 feet, *i.e.*, by 22/5280th of a mile ; thus, 10 locusts were found in an area 1/80th of a square mile, and the approximate density would be 800 per square mile. If a survey party of 5 men had been walking at a distance of about 20 to 30 feet from each other, and had counted 20 locusts in 3 miles, the population density might be worked out by first computing the total area surveyed by all the 5 men, *viz.* : 5 × 22/5280 × 3 sq. miles, or 1/16 square mile, and then calculating the density which would thus be 16 × 20, or 320 locusts per square mile. The general formula would be as follows :—

$$P=\frac{L}{M\times\frac{22}{5280}\times D} = \frac{L\times 5280}{M\times 22\times D},$$

P, being population density ; M, number of observers ; D, distance in miles ; L, number of locusts found.

If surveys are conducted during the optimum periods in respect of locust activity, this formula gives a fairly correct estimate of the population density.

During 1935, when a large incursion of locusts invaded the *rèks* of Pasni, long stretches had to be covered in order to estimate the population and much of the survey work had to be done on camel back. As the locusts flew up, they were counted, just as in the case of foot-surveys. But instead of giving a range of 11 feet on either side, double that figure was adopted in order to give due weight to the larger size of the camel, and the results obtained appeared to tally with those obtained by foot-surveys. During the subsequent years, however, when the locusts were comparatively few in numbers, camel surveys were found to be of little value and were discarded.

Owing to the extent of the area to be covered by the surveys, the scattered distribution of the locusts and the limited staff available for survey work, any precise determination of the density of population for large areas has been found to be beyond the bounds of practicability. Only random examinations have been possible and the surveys carried out can be considered to be only of the nature of "samplings." The number of locusts found in particular surveys is ultimately dependent on the peculiarities of their distribution at those times. The results of individual surveys are thus liable to vary a good deal, though carried out in the same region. In order to counteract the effects of individual variation and make the figures comparable, it was found desirable to work out the average of the density of population for the whole area surveyed. For working out the averages, the following method was adopted: The areas, in square miles, calculated for all the individual surveys, irrespective of whether locusts were noticed or not, were added together to get figures of the total extent of the area surveyed. Similarly, the total number of locusts observed in the course of all the above surveys was obtained by adding up the individual results, and from these data, the average population density for the whole area was worked out.

The present method does not aim at any high accuracy, but is useful in providing a rough estimate of the density of locust population at different places and at different times, thus supplying a common basis for comparison in regard to the effect of environmental conditions.

Moreover, what is wanted is not an absolute census of locusts at any particular place, but only a rough indication of an increase or decrease of population, due to local multiplication or to immigration from outside. The experience of the last eight years shows that variations in densities up to 10,000 per sq. mile are not of much consequence, as they represent, in general, mere fluctuations of population. On the other hand, any increase of population above that limit, especially if it is spread over a large area, should be taken somewhat seriously, as there is a likelihood, if conditions should be favourable, of the formation of concentrations of locusts in restricted situations, bringing about crowded breeding. In localities where there is a high concentration of hoppers, such as may lead to an incipient outbreak, the density of the hopper population may reach a million per square mile. A further degree of concentration—probably of the order of 20 to 100 millions per square mile, is presumably needed for the actual formation of a swarm.

Analysis of the Survey Data for 1931–1939.

The results of the surveys regularly carried out, as described above, have been compared with the weather conditions in the respective areas during each year. The sequence of events in the life of the solitary phase locusts throughout a year shows, on the whole, a striking correlation with the seasonal weather changes, and deviations of weather conditions in particular years are reflected in corresponding fluctuations of the locust population in different areas. The normal annual cycle and its variations, observed each year, are briefly described below.

The Overwintering of Adults.

Only scanty information is available with regard to the winters of 1930–31 and 1931–32. In parts of the Rajputana desert and in the Lasbela and Mekran areas considerable overwintering occurred during the winters of 1933–34, 1935–36, 1936–37 and 1937–38; in these years the breeding in the Sind-Rajputana desert during the preceding summer had been fairly heavy and continued late in the season. On the other hand, during the winters of 1932–33, 1934–35 and 1939–40, there were no overwintering adults in the Rajputana desert and very few in the Lasbela and Mekran. In 1932 there was no rainfall in Rajputana after the 15th August, and in 1934 there was none in September, while in 1938 and 1939, the monsoon rains were very poor in most parts of Sind and Rajputana, so that breeding in these four years was restricted and there was practically no late breeding. Thus, the occurrence of large numbers of overwintering adults is dependent on the late breeding in the Rajputana desert areas during the preceding summer. Locusts of the earlier brood appear to leave the desert areas by September and gradually drift westwards to Baluchistan, subsequently passing into Iran. If there is any late breeding, further flights from the desert follow during October and November, and these late adults overwinter partly in the desert, and partly in Lasbela and Mekran.

Frosts in many parts of Upper Baluchistan, especially at the altitudes above 4,000 ft., occur almost every night during the greater part of December, January and February, and there are records to indicate that swarms suffer a high percentage of mortality in these upland areas during winter, and cases of mortality among the solitary phase locusts during severe spells of cold weather have also been noticed. In winter, locusts seek the base of thick bushes like those of Siniya (*Crotalaria burhia*) during nights but they generally crawl out during daytime to bask in the sun. In the Mekran coastal areas and in the desert, winters are not severe, but sometimes, especially in the northern parts of the desert as in the Bikaner area, frosts occur on several nights during cold waves, and at such times locusts have been found dead at the foot of the bushes. The following observations made of the behaviour of locusts in a cage with wire-gauze sides kept in the open during the winter months at Quetta however, indicate that locusts can withstand fairly low temperatures. In a cage in which several hoppers had been introduced among small bushes in September, a few became adults in October, but owing to the setting in of cold weather rather early by the middle of October and the occurrence of frosts on several nights, the rest of the hoppers did not show any further growth during the winter. They were found hiding either at the base of thick bushes or in crevices between the framework of the cage and the ground during nights, and came out of their hiding places in the morning on sunny days. During the whole day they remained basking in the sun, and fed a little at midday. They did not emerge on cloudy days. The locusts—both hoppers and adults—survived till the beginning of January, so that they withstood air temperatures of 17°F. (about −8°C.), but with the fall of snow in the second week of January and the subsequent thaw, they were observed to succumb to the wet cold; the minimum temperature recorded in January was 13°F.

In the course of survey work, observations were made on the overwintering habits of a few grasshoppers. At Quetta, *Acrotylus humbertianus*, Sauss., was found overwintering under grass in a lawn at a depth of about $1\frac{1}{2}$ to 2 inches and to have survived a snowfall of 4 inches in March 1931. *Anacridium aegyptium*, L., was found hiding in a niche in a building at Quetta in February 1931. At Ahmedwall in Chagai (3,000 ft. altitude), several specimens of *Thisoicetrus persa*, Uv., were collected in March 1931, hiding in crevices in stony ground, having survived a fall of snow. At Chachro in the cultivated area of the desert, some thorn fences were dismantled in February 1935 and several grasshoppers—*Cyrtacanthacris tatarica*, L., *Anacridium aegyptium*, L., *Euprepocnemis alacris*, Serv., etc.—were found. The overwintering is probably a fairly common phenomenon among Acrididae in India.

Except during the winter of 1937–38, when hoppers were also found passing the winter in the Thar area in small numbers along with the adults, the Desert Locust would appear to overwinter only in the adult stage.

Spring Breeding on the Western Reks.

The extent and intensity of spring breeding on the western *reks* of the Mekran coast would appear to be directly commensurate with the amount of winter rainfall received. Fairly heavy spring breeding was noticed in 1933, 1935 and 1939 as a result of heavy winter-spring rainfall, while during the spring of 1932, 1934 and 1937, there was an absolute absence of breeding in consequence of an almost total failure of winter-spring rainfall. In 1931, 1936 and 1938, winter precipitation occurred all over the coast, but was below the average, and the spring breeding was, accordingly, light to moderate in character.

Late Spring Breeding in the Interior of Mekran.

a. Spring Migration.—Since 1933, regular surveys of the interior of Mekran were carried out throughout the year, and as a rule, very few locusts were noticeable in the interior of Mekran during the winter months. From March onwards, however, increasingly large numbers were usually met with. From the biometrical characters of the population met with in the interior during the period March to May in the years 1935 and 1936, and from the evidence furnished by the presence of green algae (see Ramachandra Rao, 1940) on the wings in 1937 and 1938 in similar population, it is fairly obvious that they were derived from the coastal population of Mekran. The occurrence of yellow-winged forms carrying green algae on the wings in Kachhi-Bolan area in 1937 and 1938, and the finding of a yellow-winged male with mature green algae on the wings as far north as Dalbandin on 4th April 1938, are clear indications of the existence of a general migration from the coastal areas of Mekran and Lasbela into the valleys of the interior with the advance of spring. Similar migration of swarms has been noticed in Baluchistan in the spring months during the last swarming cycle. The probable cause of such migration may be that a rise of temperature accompanied by desiccation starts earlier on the coastal plains than in the upland valleys to the north, which by reason both of a higher latitude and a greater altitude offer more suitable ecological conditions for the breeding of the locust till late in the season.

b. Development of Outbreak Centres.—As a result of the occurrence of good showers of rain in spring in the interior of Baluchistan in 1935, concentrated breeding was noticed in suitable localities between April and June, leading to the development of incipient swarms in the Kech Valley, in the Panjgur area and in south Kharan. In these cases the breeding represented the second spring generation derived from parents produced on the coast.

In 1936, an outbreak centre was found to have developed in the Kilwa area in March–April, but it was formed by the concentration of overwintered individuals of the old generation. Fairly good breeding also occurred in Kulanch at about the same time. In addition, light breeding representing the second generation of spring was noted in June at Nigor-Kan-Daf in the Panjgur area.

In 1937, owing to the failure of rains on the coast, most of the locusts would appear to have migrated into the valleys of Mekran and Upper Baluchistan. An outbreak centre developed at Sheh Lakhra in the Porali valley of Lasbela in the spring months. Heavy breeding occurred on the Kachhi Plain and in the Bolan valley in April, May and June, and there is little doubt that the infestation had been started by locusts derived from the Lasbela and Sind-Rajputana areas, where overwintering had been noticed. There was, moreover, a fair amount of breeding in the valleys of the Panjgur area, especially in the Gar-Parom section in June and July, representing the second generation of the season.

In 1938 there was little breeding in the interior in view of the defective rainfall, except in the Kulanch area.

In 1939 heavy winter rainfall occurred both on the coast and in the interior of Mekran, and good breeding was noticed in the Kulanch, Kech and Kolwa areas between March and June, and there is reason to believe that the breeding in these areas might have taken the complexion of outbreak centres if the initial locust population on the coastal areas of Mekran in the winter of 1938–39 had been greater. Heavy breeding would appear to have occurred in the Kachhi-Bolan areas also in the spring of 1939.

In 1926, the year of the commencement of the last great cycle, very heavy rainfall occurred in January, both on the coast and interior of Mekran, and led to heavy breeding on the coast. Subsequently, there was good rainfall in the interior in March and later on in May, which presumably induced widespread formation of outbreak centres in Kulanch in May, and there is reason to believe that incipient swarms developed at the same time also in the Kech and Kolwa valleys.

Movements in Summer.

The climate of the western parts of Baluchistan resembles that of the regions further west, such as Iran, Iraq and Arabia. It is of the Mediterranean type with rainfall mostly in winter and spring, and with pronounced summer drought. Rains practically cease in March or April, and by the end of April or the beginning of May there is a distinct rise of temperature accompanied by a fall of humidity. In years when there is a failure of winter rain, conditions of desiccation may set in as early as the middle of April, whereas in years of more than average rainfall, this occurs by the middle or end of May. These climatic changes generally take place more or less gradually with the advance of the season, but abrupt rises also occur fairly frequently, either as the result of a heat wave or in the wake of one of the western disturbances. High temperatures are generally accompanied by dry hot winds (*gorich*) from the north or north-west, and may persist for a week or ten days, after which milder weather may prevail till another heat wave sets in. In the Mekran area south-west winds from the coast generally prevail in the afternoons during these intervals.

With a general rise of atmospheric maximum temperatures to over 100°F. (the soil surface temperatures being naturally much higher), and a corresponding fall of humidity, locusts would seem to feel an urge to leave the area, and while the south-west winds prevail, move up through the valleys of southern Baluchistan into Kachhi and west Sind, and thence into south-west Punjab and Rajputana. On the other hand, when the north-west winds are active, locusts find their way into the coastal areas from the interior. Ultimately, however, even those reaching the coast gravitate into the desert areas via Lasbela and Sind. The following examples illustrate the variations in summer movements in various years.

In 1932 a definite incursion of locusts—mostly of the *gregaria* type—occurred on the 24th May on the Mekran *reks*, and was associated with the prevalence of dust storms from the north that had developed during the heat wave of 22nd and 23rd May in Upper Baluchistan. In July 1935, a similar incursion of locusts, but of much greater magnitude, likewise connected with the development of conditions of high saturation deficiency in the interior, was experienced in the coastal areas of Mekran and Lasbela, and in the Thar area of Sind, during the second week of the month. Similar but much lighter incursions were noted in the Pasni area in May 1936, in June 1937 and June 1938, and in all cases a sudden rise of temperature in the interior was found to be involved.

In the Sind-Rajputana desert region, regular observations were begun only from June 1933, and during the period 1933 to 1939 few locusts were noticed during the winters, none being observable by April. Specimens of a recently developed generation were always found appearing in May or June in most parts of the Sind-Rajputana desert, and as these could not have developed locally it is fairly evident that they represented migrants from the western areas of winter-spring breeding.

With the development of high temperatures in the western areas, locusts would appear to quit them in May–June and to migrate with the south-westerly winds generally prevalent at this period (except during a hot wave) towards the north-east or east into Sind, S.W. Punjab and Rajputana. As a rule, most of the early migrants reach the northern parts of the desert, the migration being directed to the southern parts only when north-westerly winds prevail as a result of an abnormal rise of temperatures in Baluchistan.

In the case of the Thar-Malliani area, locusts may arrive there directly from the western areas, but may more often be conveyed there from the north or north-east by winds connected with the passage of a monsoon depression. In 1938 no locusts were observed around Chachro till the 22nd July, when with the fall of heavy rain due to a depression, fairly good numbers were noticed on subsequent days.

In 1937, when heavy spring breeding occurred in the Kachhi and Bolan areas, locust individuals of a new generation began to appear in the Jaisalmer-Bikaner areas as early as the middle of May. As owing to lack of rainfall there was no spring breeding in the Mekran coastal areas nor any extensive multiplication in the Mekran hinterland, there is reason to believe that most of the migrants found in May and June had originated from the Kachhi-Bolan areas or from the Shah Lakhra area in Lasbela. In 1938 there was no breeding in the Kachhi area and but little in Bolan ; and few locusts were met with till the end of June in the Jaisalmer-Bikaner areas. In 1939, on the other hand, fairly good breeding occurred in the Kachhi area, and the earliest immigrations of the year –which were found in June in the Jaisalmer-Bikaner area—were presumably derived from the Kachhi area.

As the infestation found in Kachhi-Bolan area in the spring of 1937 had been derived mostly from the overwintered locusts found in the Jaisalmer-Bikaner areas, there is probably a linkage between the two areas in regard to locust breeding.

Summer Breeding.

(*a*) *Sind-Rajputana Area.*—The migrants begin to appear in the Sind-Rajputana area generally by the end of May or the beginning of June and the immigration may continue up to the middle of August. By the middle of June a fair proportion of the immigrant locusts is sexually mature, and if the monsoon rains commence by the latter half of June, as they did in 1933, 1934 and 1936, oviposition takes place almost immediately. In 1938, an inch of rainfall was recorded at Barmer on the 31st May, and hoppers were noticed there already by the end of June.

July is generally a month of good rainfall, in which egg-laying is in progress throughout the month, and the first hoppers may be expected by the middle of the month. The June–July batch forms the first monsoon brood, the new adults of which usually appear by the middle of August. Should there be good rainfall also in August, the immigrant locusts may be able to lay a second, and sometimes even a third, batch of eggs in some part or other of the desert, so that hoppers of the first generation may be found up to the middle of September and may continue to transform into adults even up to the end of September.

Generally, however, a break of 2 to 5 weeks' duration in the monsoon rainfall occurs either in July, or in July–August, or in August–September. This has the effect of causing the sand-soil moisture to dry up, and sometimes of raising the saturation deficiency of the atmosphere, as a result of which locusts find the conditions unsuitable for further egg-laying and usually leave the area.

When there is sufficient rainfall in August, adults of the new generation appearing at the beginning of August are able to attain sexual maturity by the end of August or the beginning of September, and to lay eggs that result in the second monsoon generation. As the last batches of eggs of the old generation may also be laid at the same time, an overlapping of generations is bound to occur at this period, though by the end of the breeding season the hopper population may be expected to be made up purely of the second generation.

The production of the late brood—which in effect is mostly composed of the second generation of the monsoon period—is a factor of considerable importance in locust epidemiology. The greatest increase in numbers would occur only if one fairly large brood is quickly followed by a second one within the same breeding period. Otherwise, a considerable decrease in numbers is likely to occur if the bulk of the new generation has to undergo the usual seasonal migration and hibernation before it can breed in the spring, in view of the likelihood of numerous casualties due to adverse weather conditions and natural enemies. In 1926 there was fairly heavy and almost continuous rainfall during July, August and September in the desert areas, especially in the southern parts of the desert—where heavy rain occurred in September. Consequently fairly extensive breeding in July–August was followed in September–October by a second generation mostly in the southern desert, where, favoured by the dynamics of depressions (see below), concentrated breeding was brought about, resulting in the formation of large swarms. The latter spread southwards into Cutch and Kathiawar, north-westwards into southern Punjab and westwards into Sind and Baluchistan, and thus initiated the last locust cycle of 1926–1931.

In 1935, on the other hand, good precipitation in July was followed by deficient rainfall and partial drought in August and September, so that the fairly good breeding that commenced in the wake of the incursion of considerable numbers of locusts from the west was interrupted in August, and there was only a feeble development of the second monsoon generation in September–October.

In 1933, when heavy multiplication occurred as a result of heavy rainfall, especially in the northern areas, a few loose swarms had apparently been produced, which were reported from the outskirts of the desert areas near Muttra and in the Bikaner-Bahawalpur areas.

In 1936, a considerable increase of *solitaria* population was noticed in the Jaisalmer-Bikaner areas in November as a result of late breeding induced by heavy rainfall in August, but no concentrated breeding apparently occurred.

From the experience gained during the last few years, it is obvious that August and September are rather critical months in respect of locust breeding in the desert areas, as the extent of multiplication during the particular season is entirely dependent on the character of the precipitation received during this period.

(*b*) *The Baluchistan Areas.*—Summer breeding generally occurs in the Lasbela, Kachhi and Mekran areas in which the monsoon extends its influence. Between 1931 and 1939, there was no summer rainfall in the Lasbela and Mekran areas in 1931, 1935 and 1939 and consequently no summer breeding. On the other hand, in 1932, when a depression carried heavy rainfall into the Lasbela area and into the coast and interior of Mekran during July, extensive breeding was odserveb all over these areas in July-August-September. In 1933, also, heavy rainfall occurred in July in the Lasbela area, but in Mekran the rains were comparatively light in the interior (Kolwa, Kech and Panjgur) and very light along the coast. Heavy breeding was observed in the Lasbela area between August and October, but in Mekran there was only light breeding in the interior, and none on the coast. In other years, varying amount of rainfall was associated in Lasbela with proportionately varying amount of breeding. In Mekran, however, breeding was noticed in some quantity only in 1937 and 1938 in Kolwa and Panjgur in summer.

Flights induced by Dust Storms or Thunder Storms.

In the course of intensive observations made in the Sind-Rajputana area between 1934 and 1938, it was often noticed that, soon after rainfall, locusts were found present in localities where they had not been seen previously. It was at first supposed that the presence of locusts was due to the active attraction exercised by heavy precipitation, but observations made in the course of survey work made it clear that in most cases they are brought into the area by the storms that usher in the rain. On 23rd August, 1937, large groups of solitary locusts—which were sufficiently numerous to be mistaken for a loose swarm—were reported to have been seen flying with the wind over the town of Sardarshahr at dusk just prior to the occurrence of a thunder storm. It is surmised that these locust groups had been derived from the Reni area to the north-east, where large numbers of adults of the new brood were known to have been present, and that the latter had, in view of the unusual drought that had been prevailing at the time, been excited into activity by the cool, moist winds of the oncoming thunder storm and had allowed themselves to be carried by the storm into new areas. A similar case was observed in the Kolwa area in Mekran in July 1937, when a fieldman found fairly large numbers of locusts after rain storms, though none had been found prior to rainfall. In a third case, few locusts were seen in the Nokh area during the first week of August 1936, but subsequent to the abnormally heavy precipitation during the second week (12th to 16th), large numbers of them were met with in the same area. Apparently they had been carried into the area by the cyclonic movements of the storms accompanying the passage of the depression. Further instances of this kind were noted in July 1938, when the earliest appearance of locusts during the summer synchronised with the first heavy monsoon shower at Chachro as well as at Nokh (see also Bhatia 1939).

In this connection, certain observations (as yet unpublished) which had been made by Khan Bahadur M. Afzal Husain, Dr. Taskhir Ahmad and others at Lyallpur in August 1931, on the behaviour of caged locusts, are of particular interest. A large number of locusts, captured from swarms, had been confined in a large wire-gauze cage in the open, and it was found on two occasions that the locusts began to fly about in a state of great excitation and dash against the wire-gauze sides some time before the approach of a dust storm. If in nature locusts similarly respond to changes in the atmospheric temperature, humidity and pressure associated with the approach of rain storms, they would rise into the air of their own accord to meet the winds, and thus get conveyed by them to likely areas of rainfall.

Therefore, the occurrence of thunder storms, or the passage of depressions in summer, is of special significance in the development of outbreak centres in the desert areas.

Autumn Migration.

With the withdrawal of the monsoon current from North-West India during September, the desert becomes an area of drought accompanied by high temperatures. In years of more than average precipitation during August–September, as in 1931 and 1933, the change to conditions of drought is delayed, occurring only by the middle of October. On the other hand, in years in which rainfall in August–September is defective, as in 1932, 1934 and 1935, conditions of drought develop fairly early in September, and in 1937 an unusual drought developed during a long break in the monsoon in August. During the monsoon months, the maximum temperatures in the desert rarely reach 98°F., whereas they may rise as high as 107°F. during periods of drought developing after the monsoon current ceases. The adult locusts of the solitary phase rest and bask on the surface of sandy soil, and as the temperatures on the surface of sand heated by the direct rays of the sun will naturally be high and the percentage of atmospheric moisture in such locations will also be lower than that in the screen, the discomfort caused to the insect would be very great, so that it generally tries to flee from such situations.

Locusts generally leave the Sind-Rajputana desert area in September–October, and as north-easterly or easterly winds are usually prevalent at this period, the bulk of them would appear to fly towards Sind and Baluchistan. In one carefully observed instance in September 1936 at Chachro, a dust storm that appeared from the north-eastern direction in the afternoon carried off most of the locusts in that area. As by the end of the month the population at Ambagh was found to show a sudden rise, it is surmised that a migration in a westerly direction had taken place. Similarly, in September 1937, the greater part of a fairly high locust population found in the neighbourhood of Chachro was noticed to have been swept away by a depression that passed westwards over that area on the 10th September. More usually, however, emigration from an area is gradual and may be spread over a large number of days, while the conditions of drought last. Much of the autumn migration takes place generally during October, but it may extend up to the middle of November.

In general, however, the heat abates by November, and a slight rise of humidity also occurs, so that locusts do not find the same urge to leave the area. When there is late breeding, most of the adults that are produced by the close of October or during November do not show any indications of leaving the area, and the great majority of them apparently pass the winter in the desert areas, though a certain proportion may, and do, migrate in the course of the winter season during the short spells of comparatively hot weather that sometimes develops there.

In the autumn of 1937, periodical observations were made at several points in the semi-desert area stretching between the banks of the Indus and the Hab rivers, in an attempt to get information in regard to the progress of migration. It was found that locusts were noticeable mostly on the sandy beds of various dry water-courses that drain the semi-desert country. It was also observed that, while locusts were met with during October and November, they were not seen in December, indicating the cessation of migration in winter.

From the information available, it looks as if migration takes place in the form of hops, covering about 10 to 20 miles at a time, the migrating locusts alighting wherever they find sand patches covered with light vegetation for purposes of resting and feeding. Presumably it may take about a week or ten days for migrating locusts to cover the distance between the Indus and Hab rivers, though with a strong north-east wind backing them, it may take much less.

Observations made in 1935–38 indicate that autumnal migration probably occurs in a series of waves that are generally concurrent with periods during which the dry north-east winds are prevalent in Sind, Baluchistan and Rajputana. In many cases, each wave of migration could be traced to a certain extent from the Rajputana area to the Lasbela area, and thence to the Ormara and Pasni *reks.*

Very little is known as to the routes by which migrant locusts reach the Mekran *reks* from Rajputana and *vice versa,* but there is no doubt that migration is probably guided partly by the direction of the prevalent winds and partly by the orientation of the valleys in the mountainous areas of Baluchistan through which they have to pass. It is probable, for instance, that the migrants that reach the Rumra and Pasni areas from Sind pass through the Kolwa valley. In regard to the locust populations found on the various coastal *reks* of Mekran, it was often noticed that a progressive rise of density occurred in the autumn from east to west, and it is possible that a gradual migration along the coast occurs during the autumn, winter and spring months from east to west, and probably extends into the Iranian areas.

The concentrations of locusts that are almost always noticeable on the coastal *reks* of Mekran are probably to be explained as incidents of seasonal migration. In summer, locusts get into the *reks* from the interior from a northern or north-western direction, and in autumn and winter from a north-eastern direction. On reaching the coast their migratory flights are presumably halted by a sight of the great barrier of the sea, and the attraction exercised by the *reks* with their scrub vegetation would account for their presence in such numbers along the sea-coast. It is possible that a fair number of locust individuals may be carried by strong winds across the Gulf of Oman into Arabia as, *e.g.*, in the winter of 1936–37 there was some indication that a migration of individuals had taken place across the Gulf into the Muscat-Sharjah area.

Spring Breeding in the Sind-Rajputana Desert Areas.

Usually the spring rainfall in the desert is not high enough to induce breeding, but in the spring of 1936 light breeding occurred in north Jaisalmer area. In the spring of 1937, fairly heavy rainfall occurred in the Jaisalmer-Bikaner areas, and as a result fairly widespread but light breeding was noted in April in many places in the northern parts of the desert. Adult locusts of the new generation were found in May.

In 1935, good rainfall occurred in spring but breeding did not follow on account of the absence of locusts in these areas.

During the period 1934 to 1939, no spring breeding has been noticed in the southern parts of the desert.

Parallelism of the Annual Cycle of Activities of the *Solitaria* and *Gregaria* Phases.

In view of the knowledge gained during the last nine years of the life activities of the *solitaria* phase in the Indian area of its habitat, it might be useful to compare it with what is known of its *gregaria* phase during the last locust outbreak of 1926–31. A short summary of the general scheme of swarm movements is given below.

The Winter Period.

Swarms are generally inactive during the winter months, especially during December and January. During the winters of 1928–29 and 1930–31 there was no over-wintering in the Indian area, but in 1926–27, 1927–28, 1929–30 and 1931–32 large numbers of locust swarms were found in the winter season chiefly in the coastal areas of Mekran and Lasbela, parts of the Sind valley, the Kachhi plain, parts of S.W. Punjab, the outskirts of the Indian desert, and the foothills of the Punjab ranges.

Spring Breeding and Migration.

Mekran : With the fall of winter rains, the swarms over-wintering in the coastal areas may become mature and lay eggs in suitable places. At the same time there occurs a migration from the coast into the interior, generally in a north- or north-east direction into the Kech and Kolwa valleys and thence into Jhalawan. Other swarms may move into Panjgur, Kharan and Chagai from the southern parts of Iran. From Chagai swarms may move into Sarawan and Quetta-Pishin, or into the Kandahar valley in Afghanistan *via* Shorawak and Chaman, and thence through the Arghastan valley into the Kurram valley in the N.W. Frontier Province, reaching the latter by May–June.

Kachhi : Swarms wintering in the plains of Kachhi and west Sind enter the mountain valleys of Upper Baluchistan through the gorges of the Mula, the Bolan and the Nara, ultimately finding their way into Sarawan, Sibi, Quetta-Pishin, Loralai and Zhob districts.

Punjab : Swarms become active in spring and may concentrate and breed between February and April, in districts receiving winter rainfall. There was considerable spring breeding in 1927, 1928, 1930, and little or none in 1929 and 1931. There may be some breeding in spring also in the submontane areas of the United Provinces, such as Kumaon.

Sind and Rajputana : Breeding rarely occurs in spring.

Baluchistan : Breeding takes place only in places where good rainfall has occurred. It first occurs in the low-lying coastal areas and in the Kech and Kolwa valleys (February to March), after which breeding is observed in the higher valleys, such as Panjgur, Kharan and Chagai (March to May) and lastly in the uplands of Sarawan, Quetta-Pishin and Zhob (May–June).

The adult locusts belonging to the earliest brood produced in the southern valleys may reach the uplands in the interior in April–May and may lay eggs if conditions are suitable.

Summer Migration.

Pink swarms of the adults of the new generation produced in spring in Mekran and Chagai fly in May in a north-easterly or easterly direction across Jhalawan and Sarawan till they reach west Sind, Kachhi and south-west Punjab in June. The swarms produced in the uplands in June also fly eastwards into the Sind-Punjab area.

The new generation developed in the Punjab in April–May is generally swept eastwards into the United Provinces, Central India and Bihar by the hot winds from the north-west that blow in May–June on the Indo-Gangetic plains.

The main cause of the eastward migration of swarms from Baluchistan would appear to be the development of conditions of high desiccation that set in, in the interior, at the end of spring and the prevalence of strong south-westerly winds, which carry them into Sind and the Punjab.

The pink swarms from the Baluchistan area generally reach the Sind and South-West Punjab areas in June, and gradually fly eastwards into Rajputana, the east Punjab, and the United Provinces during June–July.

Summer Breeding.

Baluchistan : The greater part of Baluchistan falls within the zone of summer drought and usually very little summer rain is received, but depressions of the monsoon period may carry considerable rainfall at times into the eastern parts of the country, such as Loralai, Sibi, Zhob, Kachhi, Jhalawan and Kolwa, in which case breeding may occur in these areas. In Lasbela, however, summer breeding is the rule, as it is subject to the influence of the monsoon.

Sind-Rajputana : With the fall of rain, the migrant swarms attain maturity, and there is considerable breeding in the sandy desert areas of Sind and Rajputana. In years of extraordinary rainfall, as in 1929, a great deal of multiplication may occur also in the alluvial areas of Sind.

Punjab and United Provinces : With the development of depressions from the Bay of Bengal, the dominant wind-direction in July–August is usually east to west, and consequently most of the swarms that had reached Bihar and Central India in June are swept back to the west and begin to breed in the Punjab and the western parts of the United Provinces.

The adults of the first generation of the monsoon begin to appear in August, and they are ready to fly in September. There is usually a single generation in summer, but if heavy late rainfall is received in August–September the old generation may continue to lay further batches of eggs and, in addition, the new generation may also begin to breed in the desert areas and in parts of the Punjab. These will assume adult condition only by October–November.

Autumn Flights.

With the withdrawal of the monsoon, north-west India becomes an area of high temperatures and low humidity, and the change in the climatic conditions has the effect of driving the swarms out of the Punjab, Rajputana and United Provinces. On the Indo-Gangetic plains, westerly winds develop in September–October and may convey the swarms eastwards into Bihar, Bengal and Assam. Some of them may also move into East Rajputana and Central India, and thence southwards into Central Provinces and Bombay Residency. In western Rajputana, some swarms may be carried southwards into the Kathiawar-Gujarat areas, but a great many are also swept westwards into Sind and Baluchistan, regions where after a period of over-wintering they can breed again in the spring following. Of the flights that move east or south few would seem to survive, as they do not meet with conditions favouring further multiplication.

Comparing the cycle of life activities of phase *gregaria*, as outlined above, with that of phase *solitaria*, one notices a remarkable parallelism in the main scheme of annual events. In fact, there is the same sequence of concurrences : (1) Over-wintering followed by breeding in the winter rain areas, (2) spring migration from the coast into the interior, followed by breeding in the upland valleys, (3) summer migration to regions eastward as a result of the development of conditions of drought in the west, (4) summer breeding in monsoon areas, and (5) autumn migration—in part at least westwards into Baluchistan owing to the autumnal rise of temperatures with the withdrawal of the monsoon current.

The main differences between the two phases would seem to lie in the greater degree of activity of phase *gregaria*. Both *solitaria* and *gregaria* are similarly affected by the same meteorological and ecological factors provoking them to make long distance migrations, but phase *gregaria* owing to its occurrence in swarms is capable, under the influence of mob psychology, of reaching longer distances and covering wider areas. The area of migration of *solitaria* individuals is confined usually to the coast and interior of British and Iranian Mekran on the west to the Rajputana desert areas on the east, but extends sometimes as far north as Chagai on the Mekran side and up to Spez and along the Bolan valley, and in the Rajputana area may extend into Patiala territory. On the other hand, swarms of *gregaria* may reach as far north as the Himalayas, as far east as Assam and as far south as the Madras Presidency.

A Change in the Conception of the Origin of Outbreaks.

At the period when the present investigations were commenced, the general view as to how locust infestation cycles recurred was somewhat as follows. With the breakdown of a locust cycle, the swarms would diminish in number and size and ultimately disappear, and simultaneously the area of their distribution would also gradually become narrowed down to the limits of their permanent breeding grounds, where they would be found as scattered individuals of the solitary phase. If favourable weather conditions, such as heavy rainfall, should occur, intensive breeding would be induced and lead to the building up of a large population during one or two successive seasons. Sooner or later, swarms of the gregarious phase would be formed and invasions of large areas of surrounding country would follow.

The observations recorded during our surveys indicated, however, firstly that the population found in the breeding grounds was rarely of a static character and was marked by strong fluctuations in density, which was affected not only by local breeding, but also by an immigration or emigration of individuals. Secondly, *solitaria* individuals have been found to be capable of migrating long distances, so that those bred in winter-rain areas can reach regions of summer rainfall and *vice versa*, at the change of the seasons, and breed there. Thirdly, phase transformation has been found to occur, not in what have been called the permanent breeding grounds, but in certain ecologically peculiar locations—the outbreak centres—often situated far from them.

From the field observations in regard to the habits and behaviour of the solitary phase in the Indian area, the following would appear to be the general sequence of events in regard to the starting of a new cycle of locust infestation in north-west India.

1. Granting that winter rainfall is heavy and early in the western areas of Baluchistan and that a fairly high population of solitary phase locusts is present on the *rek* areas of Mekran, passing the winter in the comparatively warm climate of the coastal plains, a fairly widespread and intensive breeding might be expected to occur on the sandy *rek* areas ; the new generation of locusts would begin to appear by the end of March or the beginning of April.

2. By February, with the general rise of temperatures a migration of locusts from the coast into the valleys of the hinterland would begin. By March, most of the old over-wintered locusts would have reached the interior, and in April and May the new generation from coastal *reks* would follow. The interior of Mekran is a hilly area, most of which is either rocky or stony, and soft soils—mostly fine silts or sandy loams, are to be met with only on the bottom of the valleys, on which most of the patches of cultivation are to be found, generally along the banks of streams or water-courses. In some places, small mounds of fine, wind-blown silt are also to be seen, sometimes on the banks of streams and sometimes at the base of hills. Locusts migrating into the interior are, therefore, attracted to the cultivated fields, and as the soft wet soils in such places offer suitable locations for egg-laying, crowded oviposition would occur. The hoppers hatching therefrom would appear to congregate in the cultivation and undergo a transformation of phase there.

3. Such outbreak centres might occur not only in Mekran, but also in Lasbela, Kachhi and the hill-valleys of Upper Baluchistan, such as Bolan.

4. With the development of dry weather in summer, most of the locusts produced in Baluchistan and southern Iran would appear to migrate eastwards into Sind, Rajputana and Punjab, where they begin to appear in May–June. The migration generally continues into July and August, and quite a large body of migrants may become congregated in various parts of the desert area. Breeding would begin in July, in the event of good monsoon rainfall, and the new generation of locusts produced in the desert might be produced by the end of August. Should further heavy rainfall occur in August and September, a second generation would be produced in the desert, and very often the depressions that pass over the desert from east to west would have the result of causing fairly dense concentrations to occur in the south-western or western parts of the desert, and thus bring about the formation of large swarms.

5. With the development of dry weather, in September–October, the swarms produced in the Rajputana desert area would become dispersed, most of them leaving the area westwards into the Sind-Baluchistan areas, where they can overwinter and breed in the following spring.

From the above, it is obvious that the real danger points are (1) the formation of outbreak centres in the interior of Baluchistan in late spring and (2) the intensive multiplication in the southern and western parts of the desert in September–October. It is both these areas that will have to be watched for and checked in time if the development of a new cycle of locust infestation is to be prevented.

It should be added that the complex of outbreak centres composed of the winter-rain and the summer-rain areas, connected by migrations of locust population, is probably continued into southern Iran and eastern Arabia.

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EXPERIMENTS ON THE SURVIVAL AND BEHAVIOUR OF THE ITCH MITE, *SARCOPTES SCABIEI* DeG. VAR. *HOMINIS*.

By Kenneth Mellanby, C. G. Johnson, W. C. Bartley and P. Brown.

The disease known as scabies or the itch is caused by the acarine parasite *Sarcoptes* burrowing in the horny layer of the cuticle of man. This paper describes experiments made with adult female parasites removed from scabies patients.

The Thermal Death Point.

The mites were exposed to known temperatures and humidities for periods of 10 to 30 minutes. The apparatus used consisted of a large boiling tube fitted inside a wide-mouthed thermos jar. The temperature was controlled within one-tenth degree centigrade by adding small quantities of hot water to the thermos jar. The humidity was controlled by means of about 10 ccs. of an appropriate acid-and-water mixture at the bottom of the boiling tube. As the itch mite is only 0·4 mms. long and yet is able, at a suitable temperature, to move as rapidly as two-and-a-half

TABLE I.

Thermal Death Point of ovigerous Females for Exposures of 10 *and* 30 *Minutes.*

°C.	10 minutes Humidity uncontrolled		30 minutes Pooled results for 0 and 90 per cent. R.H.		°F.
	Nos. of mites		Nos. of mites		
	Dead	Alive	Dead	Alive	
53·0±0·2	5	0			127·5±0·4
50·9±0·1	5	0			123·5±0·2
50·4±0·6			3	0	122·7±1·0
49·5±0·5	11	0	7	0	121·1±0·9
48·9±0·4	8	0			120·0±0·7
48·5±0·5			11	0	119·4±0·9
47·8±0·1	3	7			118·1±0·2
47·7±0·5 ✓			11	0	117·8±0·9 ✓
47·4±0·6	2	12	13	2	117·7±1·0
46·9±0·3	0	8			116·4±0·5
46·6±0·6			0	2	115·9±1·0
45·9±0·9			6	5	114·6±1·6
44·1±1·0			5	6	111·4±1·8
42·3±0·2			0	7	108·1±0·4

centimetres a minute, and as it can climb a vertical glass surface without difficulty, a method of keeping the animals under control in such a way that they are easily recoverable was required. For the exposures lasting 10 minutes a gauze-bottomed tube was fitted inside the boiling tube with the gauze about one centimetre above the water-acid mixture. The mites were dropped into the tube clinging to a fragment of paper. A few were lost but the majority were recovered. For the 30-minute experiments, it was possible to use an apparatus which took a minute or two to heat up to the temperature of the air without prejudicing the accuracy of the observations. The apparatus consisted of a vulcanite ring approximately one centimetre in diameter and one millimetre in thickness, covered at the bottom with bolting silk. The mites were placed on the silk and then enclosed by placing a glass coverslip on top of the ring, which was already waxed ; the glass " lid " being fixed by running a hot needle round the edge. The ring containing the mites was attached to a thread and was lowered down the tube to about a centimetre above the level of the acid.

At the end of each experiment the mites were examined under a microscope. Those that were dead could usually be distinguished by the characteristic appearance of the so-called " suckers " on the first two pairs of legs. In a living mite these are very difficult to see and never have the " text-book " sucker-like appearance so easily seen in killed mites. Furthermore, experiments have shown that any mites which were undamaged and which would burrow into the skin of volunteers, would crawl actively on a warm slide. There was seldom any doubt as to whether a mite was alive or dead, and we have counted as " dead " a small number of mites that moved feebly immediately after the experiment and died within the next few hours. The results are included in Table I. Experiments made with a 30-minute exposure show that the atmospheric humidity had no effect on the thermal death point, that is to say the animals were killed by the direct effects of heat before any adverse effects from desiccation could manifest themselves. A temperature of 49°C. (120°F.) appears to be fatal in 10 minutes and 47·5°C. (117·5°F.) in 30 minutes. Mites kept for 12 hours at 23°C. (73°F.), or at 13°C. (55°F.) had the same thermal death point as other individuals used immediately after their removal from a patient.

Survival Away from the Host.

Batches of mites were placed in vulcanite rings as described above and kept at different temperatures and humidities for varying periods. At the higher temperatures it was easy to distinguish between living and dead parasites but at the lower end of the scale (*i.e.* 5°C. (41°F.)) or below, the animals had to be warmed for several minutes before any activity was noticed. When starvation was the cause of death, as in these experiments, the " suckers " did not always take on the characteristic appearance noted after fatal exposure to heat or to a potent sarcopticidal medicament. In these circumstances it was felt that repeated warming and cooling might affect the results considerably, and each parasite was only used for one experiment at the lower temperatures.

The results are given in Table II. This shows that in warm conditions few mites survive as long as two days. In cool, moist conditions, survival may continue for as long as a fortnight, though towards the end of this period the surviving mites were probably too feeble to infect successfully. At 5°C. (41°F.) or at 0°C. (32°F.) the mites did not survive as long as at 13°C. (55°F.).

Phototaxis.

Sarcoptes appears to give neither positive nor negative phototactic reactions. When mites were placed in unidirectional light at any temperature sufficient to permit movement, their direction of progression bore no relation whatever to the direction of light. Light appeared neither to stimulate nor to inhibit movement for the animals were equally active at suitable temperatures in light or in darkness. In nature *Sarcoptes* may exhibit a diurnal rhythm, being most active at night, when transmission usually occurs, but these experiments have no bearing on this point. Incidentally, the nocturnal itching characteristic of scabies is not directly connected with the mite's activity, as is often suggested.

TABLE II.

Percentage of ovigerous Females alive on successive Days after Extraction from Host.
(Figures in brackets indicate numbers of mites used in experiment.)

Conditions		1	2	3	4	5	6	7	8	9	10	11	12	13	14
°C.	% R.H.														
27·0–29·0 82°F.	90	63 (35)	0 (12)	0 (8)											
21·0–24·5	90	84·7	30·5 (59 throughout)	6·8	1·7	0									
24·0–25·0	30	63·5	6·8 (74 throughout)	0											
12·0	90				0 (16)										
13·5–14·5	90	69·6	(23 throughout)	65·2		60·9	52·2	34·8		30·4		26·1		8·7	4·3
12·0–13·5 55°F	30	75·0	28·8 (52 throughout)	3·8	1·9	0									
5·0–6·0	90							78·6 (14)		20·0 (10)	14·3 (7)	0 (8)			
5·0–6·0 41°F.	30							27·8 (18)		16·7 (18)	20·0 (10)		0 (10)		
0 32°F	Near saturation		100·0 (3)	40·0 (5)	20·0 (5)	20·0 (5)	25·0 (8)	33·3 (6)	28·6 (7)		0 (6)	0 (12)	0 (5)	0 (7)	0 (8)

Temperature Threshold for Movement.

At winter laboratory temperatures (14–15°C.) (57–59°F.), mites placed on a slide exhibited no movements. The threshold temperature for movement was discovered by placing the animals on a warm stage of a microscope and slightly raising or lowering the temperature. The threshold for movement was observed to be between 15 and 16°C. (48°F.) and no substantial difference was found where the mite was removed immediately from the host, where it had been kept at room temperature for several hours or where it had been kept in a state of chill coma at a temperature of 9°C. (48°F.) for 48 hours.

Although the animals could move at as low a temperature as 16°C. (61°F.), any movements they made were very slow, and they seldom progressed more than a millimetre or two. It was difficult to determine the exact position of the temperature at which more rapid movement started, but below 20°C. (68°F.) one could be certain of finding the mite within one centimetre of where it had been placed on re-examining the slide at the end of an hour. Above 20°C. much more rapid movement occurred, and unless kept in sealed containers mites were very easily lost.

Movements in a Temperature Gradient.

A simple temperature gradient was produced by having a very small and carefully shaded bunsen flame under a sheet of glass, the top of which was covered with graph paper. After about a quarter of an hour a steady temperature gradient, hottest in the centre and radiating outwards, was set up, and this did not fluctuate at any point more than 1°C. (1·8°F.) in an hour. The gradient was fairly steep, about 50°C. (122°F.) in the centre, falling to 27°C. (81°F.) at five centimetres and 22°C. (71·5°F.) at 10 centimetres. The animals moved quite rapidly, but as they seldom proceeded long in a straight line, and as their movements were somewhat erratic, it was difficult to determine accurately the rate of progression. In a large series of experiments in which the mites were started off at varying temperatures between 20 and 30°C., the following points were apparent :—(*a*) No simple thermotaxis exists in *Sarcoptes*. (*b*) The mites move on the whole towards the warmest part of the gradient, and those from below 24°C. (75°F.) always found their way to the hotter part of the scale, whereas those from higher temperatures never wandered down below 24°C. (*c*) All the mites were eventually killed by the heat as they made their way towards the hottest part of the gradient. Nothing in the nature of an " avoiding reaction " to high temperature appears to exist.

Discussion.

Experiments on the infectivity of blankets and clothing (Mellanby 1941–42) have suggested that the importance of these in the transmission of scabies has generally been overestimated. Nevertheless, infection by fomites does occasionally occur, and therefore disinfestation may sometimes be advisable. The figures given here indicate the nature of the temperatures necessary if heat sterilisation is performed. Provided that the whole of the material reaches 50°C. (122°F.) for 10 minutes *Sarcoptes* will be exterminated.

The reactions of the animals to temperature may be of importance when considering how transmission takes place. Although at a suitable temperature (*i.e.* on the surface of the skin) *Sarcoptes* can move at a fairly high speed, so little movement takes place below 20°C. that it would be impossible for the animals to move from one bed to another. Again the avoidance of temperatures below 24°C. will generally be sufficient to keep the parasites on the surface of the skin and to discourage them from walking on to fomites. This helps to account for the ease with which the disease can be transmitted by direct personal contact, as compared with indirect means of transmission.

Practically the only work which has been done previously on the biology of *Sarcoptes* is that of Munro (1919), and his experiments suggest that the thermal death point is materially higher than our figures, and that humidity greatly affects the result. Our findings are in conformity with more recent work on a variety of other Arthropods.

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Summary.

(1) Adult female *Sarcoptes* were killed by 49°C. (120°F.) in 10 minutes and by 47·5°C. (117·5°F.) in 30 minutes.

(2) At 28°C. (82°F.) no *Sarcoptes* survived for two days and the majority died in 24 hours.

(3) At 13°C. (55°F.) and 90 per cent. R.H. the majority of the mites died within a week, but a few survived longer, even up to 14 days.

(4) At temperatures below 13°C. (55°F.) the mites survived for a shorter time.

(5) *Sarcoptes* gives no reactions, positive or negative to unidirectional light.

(6) Below 15°C. (59°F.) *Sarcoptes* is in chill coma. Little movement occurs below 20°C. (68°F.).

(7) In temperature gradient mites seldom, if ever, go below 24°C. (75°F.). They will walk into high temperatures which prove rapidly lethal.

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THE RELATIVE TOXICITY OF ROTENONE AND PYRETHRUM IN OIL TO THE ARGASID TICK, *ORNITHODORUS MOUBATA*, MURRAY.

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Introduction.

Central African relapsing fever is of some economic importance because, although the fatality rate may be low, sufferers are incapacitated for considerable periods. The vector is the tick, *Ornithodorus moubata*, Murray, both mature and immature stages of which are potential carriers of the disease, frequenting the huts of natives, rest-houses, etc. Contact insecticides offer a possible means of controlling this pest, and the present work was done in the course of tests on these substances against the ticks.

Methods.

The ticks were reared in an incubator at 30°C. and approximately 50 per cent. relative humidity. They were allowed periodically to feed on a rabbit. Normally the immature stages feed only once during the period between two moults, but females feed as many as six times, laying eggs about a fortnight after each feed.

Third stage nymphs were used for the main experiments, and they were fed 24 hours beforehand. Those selected for treatment were returned to the incubator immediately after being sprayed. Engorged ticks are more resistant to insecticides than unfed ones, and it is an easy matter to feed a batch for experiment all at the same time, and so ensure a uniform physiological condition throughout. Ticks are most resistant during a moult, but it is impracticable to culture groups to this condition for testing. The 24 hr. interval between feeding and spraying enabled the ticks to dry off from their wetting with the coxal secretion (a watery excretion voided during feeding), to settle down to the process of digestion and to show a certain small percentage mortality due to over-distended guts.

The spray solutions were atomised in the spraying tower described in a previous paper (Robinson, 1942*b*), and a weighed glass slide placed beside the test insects was used to estimate the dose administered. The deposit received on it was weighed to the nearest fifth of a milligram.

The standard test method adopted was the same as that in a previous paper (Robinson, 1942*b*). The nymphs were lightly fixed on their backs to a strip of index card by means of a smear of rubber solution. They were sprayed in this position and released two hours afterwards on to clean filter paper. In this way the insecticide gained access to the thin articular membranes of the legs which are relatively easily penetrated.

In the case of rotenone, some hours elapse before any perceptible effect occurs. Then the badly affected ticks become comatose and only very few of them ever recover. The less badly affected ones are usually semi-paralysed, and some recover, but others enter into fatal coma. Semi-paralysis may last for as long as three weeks and may or may not lead to death. It was considered safest to keep ticks under observation until they moulted which process was the criterion of definite recovery. The criteria of death included ingested blood visible in the body cavity through the cuticle, and absence of response to tactile stimuli over a period of at least a week.

Pyrethrum acts much more swiftly and sharply than rotenone, and perceptible stimulation occurs almost immediately after spraying. It was usually safe to decide the mortality rate within one week after a test.

A useful Solvent for Rotenone.

A solution of rotenone in oil was wanted for spraying on to the ticks, but at ordinary room temperatures this poison is hardly soluble at all in petroleum oils and sparingly so in most vegetable oils (*e.g.*, less than 1 per cent. wt./vol. in ground-nut oil). It is more soluble in castor oil (between 1 and 2 per cent. wt./vol.), but this is unsuitable for fine atomisation in ordinary spray guns owing to its high viscosity. Therefore an intermediate solvent was sought which would hold rotenone in solution with the lighter oils. It is readily soluble in acetone, benzene and chloroform, but these reagents are volatile and rather expensive. It was found that rotenone is highly soluble in coal-tar distillates such as cresols, xylenols and phenols. A xylenol fraction was selected as suitable for the present experiments, and this medium may prove of great value in derris sprays used for various pests.

In particular it was desired to compare the relative toxicities of rotenone in media of vegetable and petroleum oils. Two solutions were made for comparison.

Solution 1	*parts by volume*
Xylenol	5
ground-nut oil	15
Solution 2	
xylenol	5
ground-nut oil	3
Shell oil P 31	12

Each of these contained 1·5 per cent. wt./vol. pure rotenone. In Solution 2 the total replacement of the ground-nut oil by petroleum oil was not practicable because it caused precipitation of rotenone.

Specifications of Materials.

Pure crystalline rotenone was used for making the solutions. The spray media had the following characteristics :—

(1). *Xylenol.*

Low temperature tar-phenols distilling between 210–220°C./760 mm.

(2). *Ground-nut oil*

Specific gravity	0·918
Titer	28·5°C.
Refractive index 40°C. (Z.B.)	55·5
Solubility, True Valenta ...	88·5°C.
Iodine value	90·0 per cent.
Bromine thermal test ...	16·5
Saponification value	193 mg.
Unsaponifiable	0·5–1·0 per cent.

(3). *Shell oil P* 31

Specific gravity at 15°C. ...	0·857
Initial boiling point °C. ...	300
Viscosity (Redwood) (Seconds at 20°C.) ...	141
Flashpoint—open °C. ...	169
—closed °C. ...	160
Percent. unsulphonatable residue	99·2

Pyremist "L."

The solution used was made by filtering the maker's product and diluting it with Shell oil P31 so that it contained 0·15 per cent. pyrethrin I by weight. Pyrethrin II was not estimated, but it would be present in approximately the same amount as pyrethrin I.

The relative Toxicity of the Solutions of Rotenone, and a Comparison with Pyrethrum.

TABLE I.

The Toxicity of Oil Solutions of Rotenone and Pyrethrum to the 3rd stage Nymphs of Ornithodorus moubata *(30 ticks per dose).*

Solution	Dose of active principle mg./cm.^{2} $\times 10^4$	Percent. mortality
A. 1. 1·5 per cent. rotenone in xylenol, ground-nut, Shell oil P 31	8·4 12·6 21·0 25·0 29·4	78 93 87 100 97
A. 2. 1·5 per cent. rotenone in xylenol, ground-nut oil	16·4 20·5 24·6 28·6 41·2	33 50 57 57 63
B. 0·15 per cent. pyrethrin I in Shell oil P 31	0·9 1·3 1·8 2·7 3·2	40 43 80 87 90

TABLE II.

Regression Equations based on Data in Table I.

Solution	Regression equation	*n*	χ^2	*P*
A. 1. 1·5 per cent. rotenone in xylenol, ground-nut oil, Shell oil P 31	$y=1{\cdot}9858x+4{\cdot}0273$	3	3·6195	$0{\cdot}5>P>0{\cdot}3$
A. 2. 1·5 per cent. rotenone in xylenol, ground-nut oil	$y=1{\cdot}7793x+2{\cdot}5660$	3	1·2270	$0{\cdot}8>P>0{\cdot}7$
B. 0·15 per cent. pyrethrin I in Shell oil P 31	$y=3{\cdot}1315x+4{\cdot}7764$	3	3·4768	$0{\cdot}5>P>0{\cdot}3$

TABLE IIA.

Statistical Comparison of the Positions of the regression Lines denoted by the Equations in Table II.

Solutions	*n*	*t*	*P*
A1 and A2	6	40·400	<0·001
A1 and B	6	6·945	<0·001

The experimental data are shown in Table I, and represented graphically in fig. 1. The calculated equations of the regression lines and their statistical significance are shown in Table II (after the method of Bliss, 1935a, b). *n* is the number of degrees of freedom of a line, χ^2 is a measure of how far the experimental points diverge from the expected log-probit line and *P* is a measure of the probability that these divergences have occurred purely by chance. In these cases the values of *P* indicate that all three lines are homogeneous and that the divergences are all due to sampling errors alone.

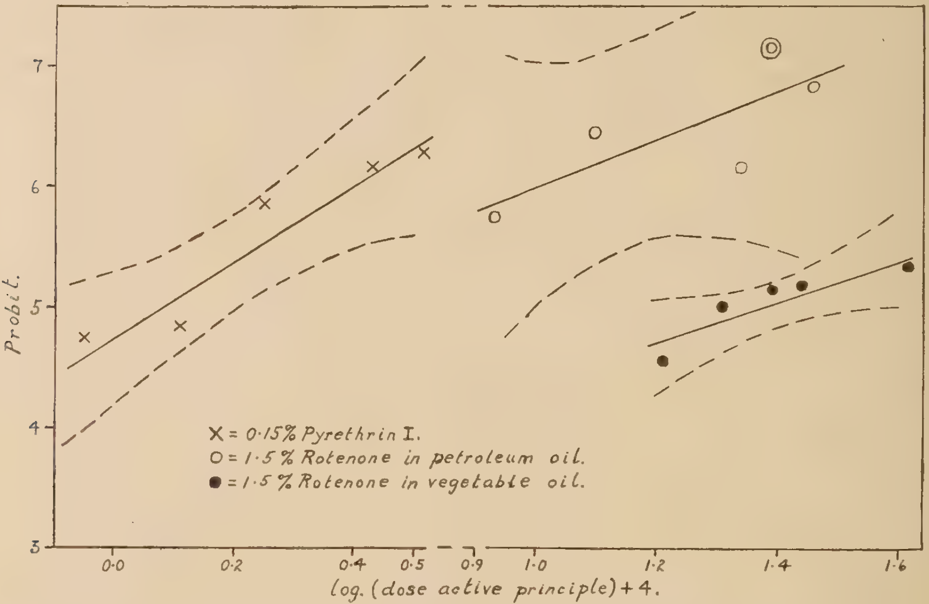

Fig. 1. Log. dose-probit lines showing the toxicity of oil solutions of rotenone and pyrethrum to 3rd stage nymphs of *Ornithodorus moubata* (30 ticks per point). The broken curves mark the limits within which the regression lines have been determined by the data. The abscissae have been made discontinuous between 0·5 and 0·9 to economise in space. (The ringed circle indicates 100 per cent. mortality.)

From fig. 1 it can be seen at a glance that, within the range of weights of rotenone explored, the solution with a substantial proportion of Shell oil P. 31 (60 per cent. by volume) is more lethal than the solution containing only ground-nut oil. For example it can be read from the graphs and Bliss's tables that a dose of $31{\cdot}62 \times 10^{-4}$ mg./cm.^{2} of pure rotenone would give a kill of 57 per cent. in ground-nut oil and 97 per cent. in the mixture containing Shell oil P. 31. This difference in toxicity is almost uniformly similar throughout the experimental range. The statistical validity is expressed in Table IIA in the comparison of solutions A1 and A2. *n* is the number of degrees of freedom of the two lines, *t* indicates the magnitude of difference in position of the lines and *P* is a measure of the probability that this difference has occurred by chance. In this case the difference in toxicity is highly significant. The xylenol-oil mixtures without rotenone both show a negligible toxicity within the range of dosage used in these experiments.

Tables I, II and IIA also include data for the toxicity of 0·15 per cent. wt./vol. pyrethrin I in Shell oil P 31. It is significantly more toxic than the two solutions of rotenone.

The greater efficiency of the petroleum oil as a carrier over the vegetable oil was expected from previous work on the penetration of pyrethrum through the cuticle of larval *Ornithodorus moubata* (Robinson, 1942*a*). In spraying experiments on the squash bug, *Anasa tristis*, DeG., Fulton and Howard (1938) used emulsions containing ground derris, derris extract and compounds of nicotine. They found that the addition of vegetable oils to the emulsions increased their toxicity more so than the addition of petroleum oil. At first sight this seems a contradiction of the present results, but it should be borne in mind that vegetable oils are better solvents of rotenone (Jones and Love, 1937) and nicotine compounds (Norton, 1941) than petroleum oils, and that in an oil-water emulsion it is mainly the oil that carries the poison through the cuticle of the insect. These facts account for Fulton and Howard's results.

With the single phase (oil) sprays used against the tick in the present experiments, the vegetable and mineral oils were passive carriers of the rotenone already in solution in xylenol. Their solvent-power was therefore not called into account, and the superiority of the petroleum oil spray must be due to the greater penetrating power of this oil as a carrier of the toxic solution. This is in conformity with the carrying properties of oils with pyrethrum, as mentioned above (Robinson, 1942*a*).

The pyrethrum spray and the more effective of the two rotenone solutions (60 per cent. mineral oil by volume) were tested on engorged female ticks, which are the most resistant of the active stages. For each spray a series of five different dosages was tried, ten ticks being used for each dosage.

For pyrethrum :—

L.D. $50 = 2{\cdot}65 \times 10^{-4}$ mg. pyrethrin I/Cm^2

L.D. $95 = 5{\cdot}05 \times 10^{-4}$ mg. pyrethrin I/Cm^2

For rotenone :—

L.D. $50 = 48{\cdot}8 \times 10^{-4}$ mg. rotenone/Cm^2

L.D. $95 = 106{\cdot}4 \times 10^{-4}$ mg. rotenone/Cm^2

The relative effectiveness of the two sprays in these tests is what would be expected from the figures for treatment of 3rd stage nymphs (Tables I and III).

These two sprays were also tested on unfed 1st stage nymphs, the least resistant of the active stages. Owing to their small size they were sprayed as they crawled on filter paper, so that their dorsal surface received the insecticide. The results are thus not strictly comparable with the others in this paper, but are useful in demonstrating the susceptibility of this stage. Four dosages were used and 25 ticks per dosage.

For pyrethrum :—

The lowest measurable dose of pyrethrin I ($0{\cdot}9 \times 10^{-4}$ mg./Cm^2) proved completely lethal.

For rotenone :—

L.D.$50 = 3{\cdot}3 \times 10^{-4}$ mg. rotenone/Cm^2

L.D.$95 = 22{\cdot}1 \times 10^{-4}$ mg. rotenone/Cm^2

In the present state of our knowledge of contact insecticides, little light can be thrown on the reason for the inverse toxicity of pyrethrum and rotenone to different insects. It is, however, interesting to note that whereas pyrethrum is more toxic to the honey-bee (Ginsburg and Schmitt, 1932) and to *Ornithodorus moubata* (present work), rotenone is more toxic to the housefly (Le Pelley and Sullivan, 1936) and to the apple aphis (Ginsburg and Schmitt, 1932).

Repetition of Results.

Four months after the experiments of the previous section, fresh solutions of the insecticides were made and used for a new lot of sprayings covering approximately the same range of dosage as before. The experimental data are in Table III.

TABLE III.

Repetition of previous Results on the Toxicity of Oil Solutions of Rotenone and Pyrethrum to 3rd stage Nymphs of Ornithodorus moubata (20 *ticks per dose*).

Solution	Dose of active principle mg./cm.^{2} $\times 10^4$	Percent. mortality
A. 1. 1·5 per cent. rotenone in xylenol, ground-nut, Shell oil P 31	8·4	45
	12·6	70
	16·8	90
	21·0	80
	25·2	85
A. 2. 1·5 per cent. rotenone in xylenol, ground-nut oil	9·8	15
	12·3	20
	16·4	15
	20·5	45
	29·5	55
B. 0·15 per cent. pyrethrin I in Shell oil P 31 ...	1·3	10
	2·0	50
	2·3	70
	2·7	70
	3·2	85

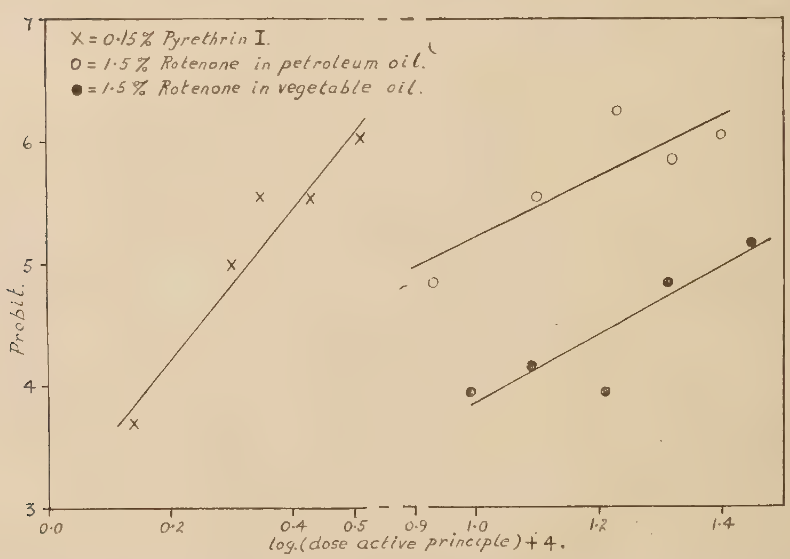

Fig. 2. Repetition of the results graphically represented in Fig. 1. Four months after the previous experiments, oil solutions of rotenone and pyrethrum were freshly made and retested (20 ticks per point). The comparison of the solutions can be seen to be materially the same as in Fig. 1.

These results are represented graphically in fig. 2 where the regression lines have been fitted by eye, and not calculated as before. Comparison with fig. 1 shows that the results are substantially the same, and that the order of toxicity is 0·15 per cent. pyrethrin I in Shell oil P 31 > 1·5 per cent. rotenone in Shell oil P 31 > 1·5 per cent. rotenone in ground-nut oil. Incidentally it should be noticed that the stock of ticks used for this repetition was distinctly more resistant than those in the original experiment, but this difference does not affect the assessment of the relative value of the three insecticides.

The Stability of the Solutions of Rotenone.

Crystalline rotenone can be stored indefinitely under dry conditions in the dark without risk of decomposition (Davidson and Jones, 1931 ; Jones and Haller, 1931).

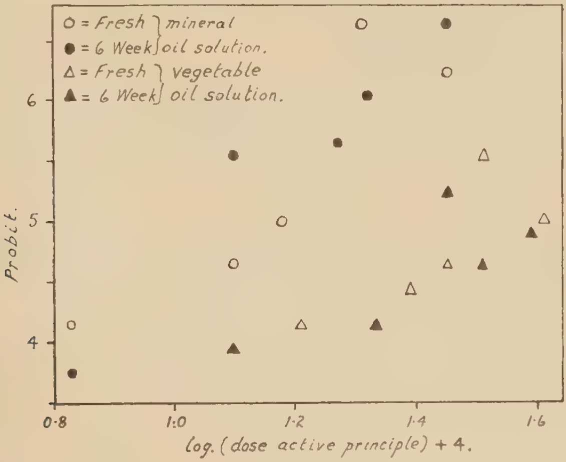

Fig. 3. Log. dose-probit points showing the toxicity of oil solutions of rotenone, made freshly, compared with that of solutions stored for six weeks. Both the petroleum (circles) and vegetable (triangles) oil solutions showed no appreciable deterioration (see Table IV). Twenty 3rd stage nymphs were used for each point.

TABLE IV.

The Toxicity of Oil Solutions of Rotenone, made freshly, compared with that of Solutions stored in the Dark for six Weeks : tested on 3rd stage Nymphs of Ornithodorus moubata *(20 ticks per dose).*

Solution : 1·5 per cent. rotenone in xylenol-oil mixture	Dose active principle $mg./cm^2 \times 10^4$	Percent. mortality
A1. Xylenol, ground-nut, Shell oil P31. Fresh	6·7	20
	12·6	35
	15·2	50
	21·0	95
	27·0	90
,, ,, ,, 6 weeks old	6·7	10
	12·6	70
	18·5	75
	21·0	85
	27·8	95
A2. Xylenol, ground-nut oil. Fresh	16·4	20
	24·6	30
	28·0	35
	32·8	70
	41·0	50
,, ,, ,, 6 weeks old	12·4	15
	21·4	20
	28·7	60
	32·8	35
	39·4	45

Jones *et al.* (1933), found that exposure to sunlight and air caused noticeable deterioration of dry deposits of rotenone within 10 days. The deterioration did not take place in the absence of oxygen.

In solution rotenone may or may not lose toxicity, according to the solvent used (Davidson and Jones, 1931 ; Jones, 1931 ; Jones and Haller, 1931). Since there were no data available for the stability of rotenone in the solvents used in the present experiments, the solutions were retested after storage for six weeks at room temperature in the dark. Their toxicity was at the same time compared with that of similar solutions made freshly. The tests were done in third stage nymphs of the tick. The results are seen in Table IV and fig. 3.

In fig. 3 it can be seen that the data representing toxicity of six-week old solutions of rotenone is similar to that for freshly made solutions, and regression lines based on the points for these solutions would not be significantly different either in position or slope. This is so for both mineral and vegetable oil media.

Conclusions.

The toxicity of a quantity of poison depends on the relative rates of its entry into the body and its being rendered harmless by excretion or chemical change. The intensity of toxic effect varies directly with the rate of entry and inversely with the rate of excretion of the poison. The superiority of petroleum oil over vegetable oil as a vehicle for rotenone seen in the foregoing experiments may be attributed to its greater speed of entry through the cuticle of the tick. This is confirmed by experiments on the rate of entry through the insect cuticle of pyrethrum in various oils (Robinson, 1942 ; Wigglesworth, 1942).

The fact that pyrethrin I used at one-tenth the concentration of rotenone is a considerably more powerful poison than the latter shows that, even in peace-time conditions, pyrethrum is much more economical to use against this tick.

Summary.

(1) Coal-tar phenols are useful intermediate solvents for making solutions of rotenone in both mineral and vegetable oils.

(2) Medium petroleum oil showed superiority to ground-nut oil as a carrier of rotenone in xylenol tested against *Ornithodorus moubata.*

(3) The solutions of rotenone in xylenol and oil showed no deterioration after storage in the dark at room temperature for six weeks.

(4) In these solutions rotenone proved far less toxic to *Ornithodorus moubata* than an equal weight of pyrethrin I in medium petroleum oil.

Acknowledgments.

My thanks are due to Professor P. A. Buxton in whose department the work was done. Dr. J. T. Martin of Rothamsted Experimental Station kindly analysed samples of Pyremist " L " (supplied by Messrs. Stafford Allen, London), and Dr. S. H. Harper, also of Rothamsted, provided a quantity of pure rotenone. The xylenol used in experiments was supplied by Dr. D. D. Pratt and Mr. Pettet, of the D.S.I.R., Chemical Research Laboratory, Teddington, who have also given useful advice concerning coal-tar products in general.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st July and 30th September, 1942 :—

Mr. E. B. Basden :—70 Coleopterous larvae ; from England.

Mr. B. P. Beirne :—25 Parasitic Hymenoptera ; from Dublin.

Mr. R. B. Benson :—5 Diptera and 250 Parasitic Hymenoptera ; from England.

Dr. B. M. Blood :—7 Parasitic Hymenoptera ; from England.

Mr. G. E. Bodkin :—93 Parasitic Hymenoptera, 39 Formicidae, 80 Rhynchota, 20 Dermaptera, and 60 Mites ; from Mauritius.

Prof. G. D. H. Carpenter :—12 Parasitic Hymenoptera and 30 cocoons ; from England.

Colonial Forest Resources Development Department :—20 Coleoptera ; from West Africa.

Coryndon Memorial Museum, Nairobi :—1,030 Coleoptera ; from East Africa.

Mr. R. L. E. Ford :—750 Parasitic Hymenoptera and 400 cocoons ; from England.

Mr. F. D. Golding, Government Entomologist :—3 Tabanidae, 17 other Diptera, 236 Coleoptera, 36 Lepidoptera, 1 species of Coccidae, 27 other Rhynchota and 39 Orthoptera ; from Nigeria.

Mr. G. H. E. Hopkins, Medical Entomolgist :—15 *Glossina* ; from Uganda.

Imperial Institute, London :—9 *Anaphe* cocoons ; from Nigeria.

Mr. F. H. Jacob :—8 Diptera ; from England.

Dr. R. H. Le Pelley :—21 Diptera and 4 puparia, 132 Parasitic Hymenoptera and 7 cocoons, and 5 Lepidoptera ; from Kenya Colony.

Mr. R. A. Lever, Government Entomologist :—2 Tabanidae, 174 other Diptera, 69 Coleoptera, 136 Parasitic Hymenoptera, 9 Lepidoptera, 6 Thysanoptera, 8 species of Coccidae, 1 species of Aphidae, 2 species of Aleurodidae, 7 other Rhynchota, 3 Mantispidae, 3 Chelifera, and 2 Lizards ; from the Fiji and Solomon Islands.

Dr. J. W. S. Macfie :—34 Diptera and 2 pupal skins, 8 Coleoptera, 4 Hymenoptera, 5 Isoptera, 5 Rhynchota and 4 Planipennia ; from the Middle East.

Royal Botanic Gardens, Kew :—2 Coleoptera and 6 larvae and samples of damage done by them ; from the Faroe Islands.

GENERAL INDEX.

A.

aberrans, *Pyrilla*.
Abutilon, Halticids on, in Africa, **229**.
Abutilon glaucum (Hambuk), new weevil on, in Sudan, **3**.
Acacia arabica (Sunt), new weevils on, in Sudan, **2**.
Acrotylus humbertianus, overwintering habits of, in India, **254**.
adersi, *Aëdes* (*Diceromyia*).
adersianus, *Culex* (*Neoculex*).
Aëdes, emended keys to adults and larvae of, in Ethiopian Region, **175**, **177**.
Aëdes adersi, in Tanganyika, **184**; populations of, **187–188**; larva of, **178**.
Aëdes aegypti, in Tanganyika, **182**; populations of, **187–193**; effectiveness of waste lubricating oils against, **237**.
Aëdes africanus, in Tanganyika, **182**.
Aëdes albicosta, in Tanganyika, **184**.
Aëdes albocephalus, in Tanganyika, **183**.
Aëdes albothorax, in Tanganyika, **184**.
Aëdes apicoargenteus, in Tanganyika, **182**.
Aëdes argenteopunctatus, in Tanganyika, **183**.
Aëdes calceatus, in Tanganyika, **183**.
Aëdes cumminsi, in huts in Kenya, **100**.
Aëdes de-boeri, in Tanganyika, **183**.
Aëdes dentatus, in huts in Kenya, **100**.
Aëdes durbanensis, in Tanganyika, **183**.
Aëdes fascipalpis, in Tanganyika, **184**.
Aëdes fowleri, in Tanganyika, **183**, **192**.
Aëdes fulgens, in Tanganyika, **182**; populations of, in tree-holes, **188**; larva of, **176**.
Aëdes furcifer, in Tanganyika, **184**.
Aëdes haworthi, in Tanganyika, **183**, **199**.
Aëdes hirsutus, in huts in Kenya, **100**.
Aëdes lamborni, in Tanganyika, **184**.
Aëdes leucarthrius, in Tanganyika, **184**.
Aëdes lineatopennis, in huts in Kenya, **101**; in Tanganyika, **184**.
Aëdes longipalpis, larva of, **176**.
Aëdes luteocephalus, in Tanganyika, **183**.
Aëdes metallicus, in huts in Kenya, **100**; in Tanganyika, **183**; populations of, **187–193**.
Aëdes minutus, in Tanganyika, **184**.
Aëdes natalensis, in Tanganyika, **184**, **189**, **192**.
Aëdes ochraceus, in huts in Kenya, **101**.
Aëdes pembaensis, in Tanganyika, **184**.
Aëdes scatophagoides, in huts in Kenya, **100**; predacious on other mosquitos in Tanganyika, **182**.
Aëdes simpsoni, in huts in Kenya, **100**; in Tanganyika, **183**; populations of, **187–193**.
Aëdes soleatus, in Tanganyika, **183**.
Aëdes taylori, in Tanganyika, **184**.
Aëdes vittatus, in Tanganyika, **183**, **192**.
Aëdimorphus (see *Aëdes*).
Aëdomyia furfurea, in Tanganyika, **181**.
aegypti, *Aëdes* (*Stegomyia*).
aegyptium, *Anacridium*.
aeneicollis, *Pagria*.
aenescens, *Pagria*.
Aerua spp., food-plants of *Schistocerca gregaria* in India, **244**, **245**.
Africa, *Pagria* spp. of, **32**; list of *Podagrica* spp. of, **229–230**; corrections to monograph on mosquitos of, **175–178**.
Africa, Portuguese East, new Halticid from, **234**.
Africa, South, food-plants of *Podagrica* spp. in, **229**; new Halticid from, **232**.
Africa, West, new Halticid from, **232**.
africana, *Podagrica*.
africanus, *Aëdes* (*Stegomyia*); *Taeniorhynchus* (*Mansonioides*).
alacris, *Euprepocnemis*.
albicauda, *Cadurcia*.
albicosta, *Aëdes* (*Banksinella*).
albiventris, *Culex* (*Neoculex*).
Albizzia lebbek, mosquitos in tree-holes of, in Tanganyika, **188**.
albocephalus, *Aëdes* (*Aëdimorphus*).
albolineatus, *Bracon*.
albothorax, *Aëdes* (*Banksinella*).
algeriensis, *Anopheles*.
Alhagi camelorum (Camel-thorn), food-plant of *Schistocerca gregaria* in India, **246**.
Almond, Indian (see *Terminalia catappa*).
Anacridium aegyptium, overwintering habits of, in India, **254**.
Anasa tristis, **277**.
angustula, *Podagrica*.
annulioris, *Culex*.

Anopheles, emended key to larvae of, in Ethiopian Region, **175** ; list of, in Palestine, **221** ; keys to spp. of, in Syria, **36** ; macroscopic differentiation of eggs of, **221.**
Anopheles algeriensis, **36** ; pattern of eggs of, **221.**
Anopheles ardensis, larva of, **175.**
Anopheles bifurcatus, auct. (see *A. claviger*).
Anopheles christyi, in huts in Kenya, **100.**
Anopheles cinereus, in huts in Kenya, **100.**
Anopheles claviger, **36** ; pattern of eggs of, **221.**
Anopheles coustani, incidence of, in Kenya, **105, 136** ; pattern of eggs of, **221.**
Anopheles coustani var. *ziemanni*, in huts in Kenya, **99.**
Anopheles elutus (see *A. maculipennis sacharovi*).
Anopheles funestus, incidence of, in Kenya, **100, 104, 114–136.**
Anopheles gambiae, seasonal incidence of, in Kenya, **100–104, 112–133.**
Anopheles garnhami, in huts in Kenya, **100.**
Anopheles hyrcanus, pattern of eggs of, **221.**
Anopheles implexus, in huts in Kenya, **99.**
Anopheles keniensis, in huts in Kenya, **100.**
Anopheles kingi, larva of, **175.**
Anopheles maculipalpis, in huts in Kenya, **100.**
Anopheles maculipennis, effectiveness of waste lubricating oils against, **238.**
Anopheles maculipennis var. *sacharovi*, pattern of eggs of, **221.**
Anopheles marteri, morphology and biology of, in Syria, **35–36.**
Anopheles mauritianus (see *A. coustani*).
Anopheles multicolor, pattern of eggs of, **221.**
Anopheles natalensis, larva of, **175.**
Anopheles natalensis var. *multicinctus*, in huts in Kenya, **100.**
Anopheles nili, in huts in Kenya, **100.**
Anopheles pharoensis, in huts in Kenya, **100** ; incidence of, **105, 136** ; pattern of eggs of, **221.**
Anopheles sergenti, pattern of eggs of, **221.**
Anopheles superpictus, pattern of eggs of, **221.**
Anopheles symesi, in huts in Kenya, **99–100.**
antennatus, *Culex*.
Antestia lineaticollis, food-plants and feeding habits of, in Kenya, **71–89.**
Apanteles flavipes, morphology and bionomics of, **53–54.**
Aphis davidsoniella (see *A. rumicis*).
Aphis fabae, summer food-plants of, in England, **161–169** ; morphology and bionomics of, on *Rumex*, **6–19** ; nomenclature of, **5.**
Aphis rumicis, morphology and bionomics of, on *Rumex*, **6–19** ; nomenclature of, **5.**
apicalis, *Podagrica*.
apicoargenteus, *Aëdes* (*Stegomyia*).
Arctium lappa, tests with *Aphis rumicis* and, **18** ; summer food-plant of *A. fabae*, **161.**
ardensis, *Anopheles*.
argenteopunctatus, *Aëdes* (*Aëdimorphus*).
aruwimiana, *Podagrica*.
ascaniae, *Ephialtes*.
Aspergillus flavus, infesting *Proceras venosatus* in Ceylon, **44.**
Astragalus, food-plant of *Schistocerca gregaria* in India, **246.**
auratocauda, *Cadurcia*.
aureus, *Taeniorhynchus* (*Coquillettidia*).
aurites, *Taeniorhynchus* (*Coquillettidia*).
Australia, *Pagria* spp. of, **31** ; new Eumolpid from, **33.**
australis, *Pagria*.

B.

Bajri (see *Pennisetum typhoideum*).
balfouri, *Uranotaenia*.
Bamboo Pots, methods of obtaining index of population density of mosquitos with, **188.**
Bamia (see *Hibiscus*).
Banana, *Aëdes adersi* breeding in, **179.**
Banksinella (see *Aëdes*).
Beans (*Phaseolus*), Eumolpid on, in Singapore, **31.**
Beta vulgaris, tests with *Aphis rumicis* and, **17, 18** ; summer food-plant of *A. fabae*, **161.**
bevinsi, *Podagrica*.
bifurcatus, auct., *Anopheles* (see *A. claviger*).
bipunctata, *Pagria* ; *Sibinia*.
bipunctifer, *Schoenobius*.
bipustulata, *Pagria*.
bitaeniorhynchus, *Culex*.
borbonensis, *Cadurcia*.
Borer, status of name, **68.**
Bracon albolineatus, introduced into Mauritius from Ceylon against sugar-cane borers, **50, 57–61** ; morphology and bionomics of, **49–53.**

brevipalpis, Megarhinus.
British Isles, morphology and biology of *Aphis* spp. in, **5–19, 161–169.**
brunnula, Sibinia.
burmanica, Pagria.

C.

Cabbage, food-plant of *Schistocerca gregaria* in India, **244, 245.**
Cadurcia spp., characters of, **225.**
Cadurcia plutellae, sp. n., parasite of *Plutella maculipennis* in Kenya, **223.**
Cajanus indicus, new weevil on, in Sudan, **2.**
calceatus, Aëdes (*Stegomyia*).
Camel-thorn (see *Alhagi camelorum*).
capitata, Ceratitis.
Capsella bursa-pastoris, summer food plant of *Aphis fabae*, **161.**
Cassia fistula, new weevil on, in Sudan, **3.**
casta, Cadurcia.
Casuarina equisetifolia, mosquitos in tree-holes of, in Tanganyika, **188.**
caudatus, Ephialtes.
cautella, Ephestia.
cephalonica, Corcyra.
Cephalosporium indicum, infesting *Chilo zonellus* in Ceylon, **45.**
Ceratitis capitata, on coffee in Kenya, **80.**
Ceylon, food-plants of Eumolpids in, **31**; natural enemies of *Proceras sacchariphagus* in, and their introduction into Mauritius, **39–65.**
ceylonica, Pagria.
Chenopodium album, tests with *Aphis rumicis* and, **18**; summer food-plant of *A. fabae*, **161.**
Chilo dichromellus, in Ceylon, **41.**
Chilo infuscatellus, Xanthopimpla stemmator parasitising, in Formosa, **48.**
Chilo simplex, C. zonellus recorded as, in India and Ceylon, **40** (see *C. suppressalis*).
Chilo suppressalis, synonymy and distribution of, **40**; parasite of, in Formosa, **53.**
Chilo zonellus, occurrence, parasites and diseases of, in Ceylon, **40, 45–46.**
christyi, Anopheles (*Myzomyia*).
Chrozophora, food-plant of *Schistocerca gregaria* in India, **246.**
chrysogaster, Eretmapodites.
cicatricosa, Ephialtes (*Pimpla*).
cinereus, Anopheles (*Myzomyia*).
Cirsium arvense, summer food-plant of *Aphis fabae*, **161**; tests with *A. rumicis* and, **18.**
claviger, Anopheles.
Clover, new weevil on, in Sudan, **2.**
Coconut (*Cocos nucifera*), mosquitos in tree-holes of, in Tanganyika, **188.**
Codling Moth (see *Cydia pomonella*).
Coelomomyces africanus, infesting *Anopheles* in Africa, **137.**
coerulea, Podagrica.
coffeae, Diarthrothrips; *Lygus.*
Coffee (*Coffea arabica*), food-plant of *Antestia lineaticollis* in Kenya, **71**; method of sampling thrips populations on, in Kenya, **147–148.**
Coix lachryma-jobi, Proceras venosatus not found on, in Ceylon, **44.**
Colletotrichum coffeanum, infesting coffee in Kenya, **76.**
conglomerata, Pagria.
congoensis, Podagrica.
continentalis, Podagrica.
Convolvulus pleuricollis, food-plant of *Schistocerca gregaria* in India, **245.**
Coquillettidia (see *Taeniorhynchus*).
Corcyra cephalonica, **62.**
Cordia, not suitable for *Xanthopimpla* in Mauritius, **57.**
corpulenta, Podagrica.
costatipennis, Pagria; *Podagrica.*
Cotton, Eumolpid on, in Nigeria, **31**; Halticid on, in Nyasaland, **229**; new weevils on, in Sudan, **1–3.**
coustani, Anopheles.
Cowpea (see *Vigna*).
Crambus seychellellus, Trichogramma experimentally bred from, in Mauritius, **62.**
crassiseta, Ephialtes.
Cremastus flavo-orbitalis, parasite of *Chilo zonellus* in Ceylon, **45.**
Crotalaria, Eumolpid on, in Java, **31.**
Crotalaria burhia (Siniya), food-plant of *Schistocerca gregaria* in India, **245, 254.**
Culex, emended key to larvae of, in Ethiopian Region, **177.**
Culex adersianus, larva of, **179.**
Culex albiventris, **179.**
Culex annulioris, in huts in Kenya, **101**; in Tanganyika, **185.**
Culex antennatus, in huts in Kenya, **101, 112**; in Tanganyika, **185**; incidence of, **122–136.**
Culex bitaeniorhynchus, in huts in Kenya, **101**; in Tanganyika, **185.**
Culex decens, in Tanganyika, **185.**
Culex duttoni, in huts in Kenya, **101**; in Tanganyika, **185.**
Culex ethiopicus, in Tanganyika, **185.**
Culex fatigans, in huts in Kenya, **101**; in Tanganyika, **185.**
Culex guiarti, in Tanganyika, **185.**
Culex hancocki, in huts in Kenya, **101.**

Culex horridus, in Tanganyika, **185.**
Culex inconspicuosus, in Tanganyika, **185.**
Culex ingrami, in huts in Kenya, **101.**
Culex invidiosus, in Tanganyika, **186.**
Culex laurenti (see *C. antennatus*).
Culex nebulosus, in huts in Kenya, **101.**
Culex nebulosus var. *pseudocinereus*, in Tanganyika, **185.**
Culex perfuscus, in Tanganyika, **186.**
Culex pipiens, in Tanganyika, **186.**
Culex poicilipes, in Tanganyika, **186.**
Culex simpsoni, in huts in Kenya, **101** ; in Tanganyika, **186.**
Culex sitiens, in Tanganyika, **186.**
Culex thalassius, in Tanganyika, **186.**
Culex theileri, in Tanganyika, **186.**
Culex tigripes, in huts in Kenya, **101** ; in Tanganyika, **185.**
Culex trifoliatus, in Tanganyika, **186.**
Culex tritaeniorhynchus, in Tanganyika, **186.**
Culex univittatus, in huts in Kenya, **101** ; in Tanganyika, **186.**
Culex vansomereni, in huts in Kenya, **101.**
Culex watti, in Tanganyika, **186.**
Culiciomyia (see *Culex*).
cumminsi, *Aëdes* (*Aëdimorphus*).
cupripennis, *Podagrica*.
Cuticle, factors affecting permeability of, by insecticides, **205–218.**
Cydia pomonella, new Ichneumonid parasite of, in France and Germany, **171.**
cydiae, *Ephialtes*.
Cyperus arenarius, food-plant of *Schistocerca gregaria* in India, **244.**
Cyrtacanthacris tatarica, overwintering habits of, in India, **254.**

D.

dalmani, *Podagrica*.
davidsoniella, *Aphis* (see *A. rumicis*).
de-boeri, *Aëdes* (*Stegomyia*).
decens, *Culex*.
decolorata, *Podagrica*.
Denmark, distribution of *Diprion polytomum* in, **152.**
dentatus, *Aëdes* (*Aëdimorphus*).
depressa, *Cadurcia*.
deserticola, *Podagrica*.
Diamond-back Moth (see *Plutella maculipennis*).
Diarthrothrips coffeae, method of sampling populations of, on coffee in Kenya, **147–148.**
Diatraea mauriciella (see *Proceras sacchariphagus*).
Diatraea saccharalis, the name of New World sugar-cane borer, **67.**
Diatraea striatalis, a synonym of *Proceras sacchariphagus* and not *P. venosatus*, **40, 68.**
Diatraea venosata (see *Proceras*).
Diceromyia (see *Aëdes*).
dichromellus, *Chilo*.
dilecta, *Podagrica*.
Diprion polytomum, distribution of, in Scandinavian and E. Baltic countries, **149–159.**
Dock (see *Rumex*).
Doralis (see *Aphis*).
Dunnius (see *Aëdes*).
durbanensis, *Aëdes* (*Aëdimorphus*).
duttoni, *Culex*.

E.

Eclipta alba, new weevil on, in Sudan, **2.**
elutella, *Ephestia*.
elutus, *Anopheles* (see *A. maculipennis sacharovi*).
Ephestia cautella, **62** ; larva of, **21–25.**
Ephestia elutella, larva of, **21–24.**
Ephestia figulilella, larva of, **25.**
Ephestia kühniella, larva of, **21–24.**
Ephialtes ascaniae, **172.**
Ephialtes caudatus, parasite of *Cydia pomonella*, **171.**
Ephialtes cicatricosa, parasite of *Sesia*, **171.**
Ephialtes crassiseta, parasite of *Cydia pomonella*, **171.**
Ephialtes cydiae, sp. n., parasite of *Cydia pomonella* in France and Germany, **172.**
Ephialtes extensor (see *E. punctulatus*).
Ephialtes longiseta (*haemorrhoidalis*), parasite of *Grapholitha pactolana*, **171.**
Ephialtes punctulatus, **171.**
Ephialtes (*Exeristes*) *roborator*, **52** ; synonymy of, **171.**
Ephialtes sanguinicollis (see *E. ascaniae*).
Ephialtes tenuiventris, **171.**
Ephialtes terebrans, **171.**
Eretmapodites chrysogaster, in Tanganyika, **184.**
Eretmapodites intermedius, in Tanganyika, **184.**
Eretmapodites quinquevittatus, in Tanganyika, **184** ; populations of, **187–188.**
Eretmapodites subsimplicipes, in Tanganyika, **184.**
Eritrea, new weevil from, **1.**

Estonia, distribution of *Diprion polytomum* in, **158.**

ethiopicus, Culex.

Eucosma schistaceana, Xanthopimpla stemmator parasitising, in Formosa, **48.**

Euonymus europaeus, tests with *Aphis rumicis* and, **17, 18 ;** winter food-plant of *A. fabae*, **161.**

Eupatorium, not suitable for *Xanthopimpla* in Mauritius, **57.**

Euprepocnemis alacris, overwintering habits of, in India, **254.**

European Spruce Sawfly (see *Diprion polytomum*).

evanescens, Trichogramma.

Exeristes roborator (see *Ephialtes*).

extensor, Ephialtes (see *E. punctulatus*).

F.

fabae, Aphis (*Doralis*).

fascicauda, Cadurcia.

fascipalpis, Aëdes (*Diceromyia*).

fatigans, Culex.

ferruginea, Podagrica.

Ficalbia mimomyiaformis, in Tanganyika, **181.**

Ficalbia plumosa, in Tanganyika, **181.**

Ficalbia splendens, in Tanganyika, **181.**

figulilella, Ephestia.

Finland, distribution of *Diprion polytomum* in, **155–157.**

Finlaya (see *Aëdes*).

flavipes, Apanteles.

flavo-orbitalis, Cremastus.

flavopustulata, Pagria.

Formosa, hosts of *Xanthopimpla stemmator* in, **48.**

fowleri, Aëdes (*Aëdimorphus*).

France, new Ichneumonid parasite of *Cydia pomonella* in, **173.**

fulgens, Aëdes (*Finlaya*).

fulvipes, Nodostoma (see *Pagria xanthopus*).

funestus, Anopheles (*Myzomyia*).

furcifer, Aëdes (*Diceromyia*).

furfurea, Aëdomyia.

fusca, Uranotaenia.

fuscopennatus, Taeniorhynchus (*Coquillettidia*).

G.

gambiae, Anopheles (*Myzomyia*).

garnhami, Anopheles (*Myzomyia*).

Germany, new Ichneumonid parasite of *Cydia pomonella* in, **173.**

glabrata, Podagrica.

Gold Coast, food-plants of *Podagrica* spp. in, **229.**

gossypii, Pagria ; Smicronyx.

graphica, Pagria.

Grapholitha pactolana, Ichneumonid parasite of, **171.**

grata, Pagria (*Nodostoma*).

gregaria, Schistocerca.

Grewia flavescens, new weevil on, in Sudan, **3.**

guiarti, Culex.

H.

haemorrhoidalis, Ephialtes (see *E. longiseta*).

Hambuk (see *Abutilon glaucum*).

hancocki, Culex.

Harpagomyia taeniarostris, in Tanganyika, **181.**

haworthi, Aëdes (*Aëdimorphus*).

Heliotropium undulatum (Marrand), food-plant of *Schistocerca gregaria* in India, **243–246.**

Hibiscus (Bamia), Halticids on, in Africa, **229.**

hirsutus, Aëdes (*Aëdimorphus*).

Hollyhock, Halticid on, in Cape Province, **229.**

hominis, Sarcoptes scabiei.

horridus, Culex (*Neoculex*).

humbertianus, Acrotylus.

hyrcanus, Anopheles.

I.

illisalis, Omphisa.

implexus, Anopheles.

impressipennis, Podagrica.

inarcualis, Simplicia.

incerta, Pagria.

inconspicuosus, Culex (*Mochthogenes*).

India, studies on *Schistocerca gregaria* in, **241–265.**

Indigofera cordifolia, food-plant of *Schistocerca gregaria* in India, **245.**

inferens, Sesamia.

infuscatellus, Chilo.

ingibbosa, Pagria.

ingrami, Culex.

Insecticides, insect integument in relation to contact, **205–218.**

intermedius, Eretmapodites.

interpunctella, Plodia.

invidiosus, Culex.

Itch Mite (see *Sarcoptes scabiei hominis*).

J.

Java, food-plants of Eumolpids in, **31.**
Jowari (see *Sorghum*).

K.

kanarensis, Pagria.
keniensis, Anopheles (*Myzomyia*).
Kenya Colony, food-plants and feeding habits of *Antestia lineaticollis* in, **71–89 ;** new Halticids from, **231, 233, 234 ;** incidence of mosquitos in native huts in, **91–142 ;** new Tachinid parasite of *Plutella maculipennis* in, **223 ;** method of sampling thrips populations on coffee in, **147–148.**
Kharzan (see *Sericostoma pauciflorum*).
kibonotensis, Podagrica.
kiesenwetteri, Smicronyx.
kingi, Anopheles.
kühniella, Ephestia.

L.

laevifrons, Pagria.
lamborni, Aëdes (*Aëdimorphus*).
Larat, new Eumolpid from, **34.**
Larvascope, for identifying living Culicine larvae, **27–29.**
Latvia, distribution of *Diprion polytomum* in, **158.**
laurenti, Culex (see *C. antennatus*).
leefmansi, Cadurcia.
leucarthrius, Aëdes (*Aëdimorphus*).
lineata, Podagrica.
lineaticollis, Antestia.
lineatopennis, Aëdes (*Banksinella*).
Lithuania, distribution of *Diprion polytomum* in, **157.**
litura, Prodenia.
liturata, Pagria.
Locust, Desert (see *Schistocerca gregaria*).
longipalpis, Aëdes.
longiseta, Ephialtes.
lucens, Cadurcia.
luteocephalus, Aëdes (*Stegomyia*).
lutescens, Megarhinus.
Lutzia (see *Culex*).
Lygus coffeae, on coffee in Kenya, **81.**

M.

Macrocentrus sp., morphology and bionomics of, in Ceylon, **54.**
maculata, Podagrica.
maculiceps, Podagrica.
maculipalpis, Anopheles (*Myzomyia*).
maculipennis, Anopheles ; *Plutella.*
Maize (*Zea mays*), *Chilo zonellus* on, in India and Ceylon, **53 ;** food-plant of *Proceras venosatus*, **44 ;** attacked by *Schistocerca gregaria* in India, **245.**
Malaya, food-plants of Eumolpids in, **31.**
Malva, Halticids on, in E. Africa, **229.**
Mango (*Mangifera indica*), mosquitos in trunks of, in Tanganyika, **188.**
Mansonioides (see *Taeniorhynchus*).
Marrand (see *Heliotropium undulatum*).
marshalli, Podagrica.
marteri, Anopheles.
mashonaensis, Uranotaenia.
mauriciella, Diatraea (see *Proceras sacchariphagus*).
mauritia, Spodoptera.
mauritianus, Anopheles (see *A. coustani*).
Mauritius, natural enemies of *Proceras sacchariphagus* and their introduction into, from Ceylon, **39–65.**
Megarhinus brevipalpis, in Tanganyika, **181.**
Megarhinus lutescens, in Tanganyika, **181.**
melanopa, Podagrica.
metallicus, Aëdes (*Stegomyia*) ; *Taeniorhynchus* (*Coquillettidia*).
Metanastria punctata, Xanthopimpla stemmator parasitising, in Formosa, **48.**
Mimomyia (see *Ficalbia*).
mimomyiaformis, Ficalbia (*Mimomyia*).
minor, Pagria.
minutum, Trichogramma.
minutus, Aëdes (*Aëdimorphus*).
Mochthogenes (see *Culex*).
Mosquitos, notes on and corrections to monograph of, in Ethiopian Region, **175–178 ;** incidence of, in native huts in Kenya, **91–142 ;** list of, in Tanganyika, **187–193 ;** macroscopic differentiation of eggs of, **221.**
Mosquito Larvae, tests for mineral oils against, **195–203 ;** utilisation of waste lubricating oil against, **235–240 ;** method of transporting living, **227–228 ;** larvascope for identifying living, **27–29.**
moubata, Ornithodorus.
Mucidus (see *Aëdes*).
muiri, Pagria.
multicinctus, Anopheles (*Myzomyia*) *natalensis.*
multicolor, Anopheles.

N.

natalensis, *Aëdes* (*Dunnius*); *Anopheles* (*Myzomyia*).
nebulosus, *Culex* (*Culiciomyia*).
Nematospora spp., *Antestia* associated with, on coffee in Kenya, **71, 75.**
Neoculex (see *Culex*).
New Britain, new Eumolpid on cowpea from, **32.**
Nigeria, Eumolpid on cotton in, **31**; *Podagrica uniformis* in, **229.**
nigerrimus, *Taeniorhynchus* (*Mansonioides*) *africanus*.
nigriceps, *Podagrica*.
nigriventris, *Podagrica*.
nili, *Anopheles* (*Myzomyia*).
Nisotra (see *Podagrica*).
nivella, *Scirpophaga*.
Nodostoma (see *Pagria*).
Norway, distribution of *Diprion polytomum* in, **152–153.**
nubilalis, *Pyrausta*.
Nyasaland, food-plants of *Podagrica* spp. in, **229.**

O.

Ochra, Halticid on, in Gold Coast, **229.**
ochraceus, *Aëdes* (*Aëdimorphus*).
octoguttalis, *Thliptoceras*.
Oecophylla smaragdina, **52.**
Oils, as carriers for rotenone against ticks, **274–275**; utilisation of waste lubricating, against mosquito larvae, **235–240**; tests with, against mosquito larvae, **195–203.**
Omphisa illisalis, *Xanthopimpla stemmator* parasitising, in Formosa, **48.**
o'neili, *Podagrica*.
orichalcea, *Plusia*.
ornata, *Podagrica*.
Ornithodorus moubata, studies on toxicity of pyrethrum and rotenone in oil against, **273–281.**
Oryza sativa, food-plant of *Proceras venosatus*, **44.**
ovatipennis, *Podagrica*.

P.

pactolana, *Grapholitha*.
Pagria, list of species of, **31–32.**
Pagria australis, sp. n., from Queensland, **33.**
Pagria muiri, sp. n., from Larat, **34.**
Pagria vignaphila, sp. n., on cowpea in New Britain, **32.**
Palestine, list of *Anopheles* spp. in, **221.**
pallida, *Podagrica*.
pallidicolor, *Pagria*.
pallidipes, *Podagrica*.
Panicum maximum, food-plant of *Proceras venosatus*, **44.**
Papaver rhoeas, tests with *Aphis rumicis* and, **18**; summer food-plant of *A. fabae*, **161.**
Pavetta elliottii, food-plant of *Antestia lineaticollis* in Kenya, **71.**
Pavonia, Halticid on, in S. Africa, **229.**
pembaensis, *Aëdes* (*Skusea*).
Pennisetum spp., insects on, **44, 245.**
perfuscus, *Culex*.
persa, *Thisoicetrus*.
pharoensis, *Anopheles* (*Myzomyia*).
Phaseolus (see Beans).
Phoma, *Antestia* associated with, on coffee in Kenya, **75.**
Phragmatiphila truncata, parasite of, in Queensland, **53.**
Picea excelsa, food-plant of *Diprion polytomum* in Europe, **150.**
Pimpla cicatricosa (see *Ephialtes*).
pipiens, *Culex*.
Pistia, mosquitos associated with, in Tanganyika, **181, 182.**
plagiata, *Tiracola*.
plicata, *Pagria*.
Plodia interpunctella, larva of, **21, 22.**
plumosa, *Ficalbia* (*Mimomyia*).
Plusia orichalcea, *Xanthopimpla stemmator* parasitising, in India, **48.**
Plutella maculipennis (Diamond-back Moth), new Tachinid parasite of, in Kenya, **223.**
plutellae, *Cadurcia*.
Podagrica, classification and new species of, in Africa, **229–234.**
poicilipes, *Culex*.
polytomum, *Diprion*.
pomonella, *Cydia*.
Proceras sacchariphagus (*Diatraea mauriciella*), natural enemies of, in Ceylon and their introduction into Mauritius, **39–65**; earliest name for sugar-cane borer of the Old World, **67.**
Proceras (*Diatraea*) *venosatus*, food-plants and natural enemies of, in Ceylon, **43–44**; distinct from *P. sacchariphagus*, **39, 68.**
Prodenia litura, experimental host of parasites of sugar-cane borers, **48, 52.**
prolixus, *Rhodnius*.
pseudocinereus, *Culex* (*Culiciomyia*) *nebulosus*.
Psychotria nairobiensis, food-plant of *Antestia lineaticollis* in Kenya, **71.**
punctata, *Metanastria*.

puncticollis, Podagrica.
punctulatus, Ephialtes.
Pyrausta nubilalis, Xanthopimpla stemmator parasitising, in Formosa, **48.**
Pyrethrum (in Oils), factors affecting permeability of insect cuticle by, **205–218 ;** more toxic to *Ornithodorus moubata* than rotenone, **273–281.**
Pyrilla aberrans, on sugar-cane in Ceylon, **42.**

Q.

quadriplagiata, Podagrica.
quinquevittatus, Eretmapodites.

R.

restituens, Pagria.
Rhodnius prolixus, factors affecting permeability of cuticle of, by contact insecticides, **207–217.**
Rice, pests of, in Ceylon, **45.**
risbeci, Podagrica.
roborator, Ephialtes (*Exeristes*).
Rotenone, in oil, less toxic to *Ornithodorus moubata* than pyrethrum, **273–281.**
Rumex spp. (Dock), bionomics of *Aphis* spp. on, **6–19, 161.**
rumicis, Aphis (*Doralis*).

S.

saccharalis, Diatraea.
sacchariphagus, Proceras.
Saccharum spp., food-plants of *Proceras venosatus,* **44.**
sacharovi, Anopheles maculipennis.
sanguinicollis, Ephialtes (see *E. ascaniae*).
Sarcoptes scabiei var. *hominis,* experiments on survival and behaviour of, at various temperatures, **267–271.**
scabiei, Sarcoptes.
Scabies (see *Sarcoptes scabiei hominis*).
scatophagoides, Aëdes (*Mucidus*).
schistaceana, Eucosma.
Schistocerca gregaria (Desert Locust), studies on, in India, **241–265.**
Schoenobius bipunctifer, on rice in Ceylon, **45.**
Scirpophaga nivella, on rice in Ceylon, **45 ;** *Xanthopimpla stemmator* parasitising, in Formosa, **48.**
semblidis, Trichogramma.
semiviolacea, Cadurcia.
Senna, new weevils on, in Sudan, **2, 3.**
sergenti, Anopheles.
Sericostoma pauciflorum (Kharzan), food-plant of *Schistocerca gregaria* in India, **245.**
Sesamia inferens, parasites of, in Formosa, **48, 53.**
Sesamia vuteria, parasitised by *Xanthopimpla stemmator* in Mauritius, **56.**
seychellellus, Crambus.
Sibinia bipunctata, **2.**
Sibinia brunnula, sp. n., food-plants of, in Sudan, **2.**
Sibinia sodalis, **2, 3.**
Sibinia sudanica, sp. n., food-plants of, in Sudan, **3.**
Sibinia vitticollis, sp. n., food-plants of, in Sudan, **2.**
Sida cordifolia, Halticid on, in Uganda, **229.**
Sierra Leone, food-plants of *Podagrica* spp. in, **229.**
signata, Pagria.
simplex, Chilo.
Simplicia inarcualis, failure to rear *Xanthopimpla stemmator* on, in Mauritius, **56.**
simpsoni, Aëdes (*Stegomyia*) ; *Culex.*
Singapore, Eumolpid on beans in, **31.**
Siniya (see *Crotalaria burhia*).
sitiens, Culex.
sjöstedti, Podagrica.
Skusea (see *Aëdes*).
smaragdina, Oecophylla.
Smicronyx gossypii, sp. n., on cotton in Sudan and Eritrea, **1.**
Smicronyx kiesenwetteri, **2.**
Solanum nigrum, summer food-plant of *Aphis fabae,* **161.**
soleatus, Aëdes (*Stegomyia*).
Sorghum (Jowari), new weevil on, in Sudan, **3 ;** food-plant of *Schistocerca gregaria* in India, **244, 245.**
Sorghum durra, Proceras venosatus not found on, in Ceylon, **44.**
Sorghum vulgare, food-plant of sugar-cane borers, **44, 53.**
spadicea, Podagrica.
Sphaerosoma aucheri, food-plant of *Schistocerca gregaria* in India, **246.**
spilota, Podagrica.
splendens, Ficalbia (*Mimomyia*).
Spodoptera mauritia, experimental host of parasite of sugar-cane borers, **52.**
Spruce, Norway (see *Picea excelsa*).
Spruce Sawfly, European (see *Diprion polytomum*).
Stachytarpheta, not suitable for *Xanthopimpla* in Mauritius, **57.**
Stegomyia (see *Aëdes*).

stemmator, Xanthopimpla.
striatalis, Diatraea (see *Proceras sacchariphagus*).
suahelorum, Podagrica.
subsimplicipes, Eretmapodites.
Sudan, food-plants of *Podagrica* spp. in, **229** ; new weevils from, **1–3.**
sudanensis, Podagrica.
sudanica, Sibinia.
Sugar-cane, bionomics and control of *Diatraea* and *Chilo* on, in Ceylon, **39–54** ; transportation, etc., of parasites of borers of, from Ceylon to Mauritius, **54–65.**
sumatrensis, Pagria.
Sunt (see *Acacia arabica*).
superpictus, Anopheles.
suppressalis, Chilo.
suturalis, Pagria.
suzannae, Podagrica.
Sweden, distribution of *Diprion polytomum* in, **153–155.**
symesi, Anopheles.
Syria, *Anopheles marteri* in, **35** ; keys to *Anopheles* in, **36.**

T.

taeniarostris, Harpagomyia.
Taeniorhynchus africanus, incidence of, in Kenya, **106–108, 115–136** ; in Tanganyika, **182.**
Taeniorhynchus africanus var. *nigerrimus*, in huts in Kenya, **100.**
Taeniorhynchus aureus, in Tanganyika, **182.**
Taeniorhynchus aurites, in huts in Kenya, **100** ; in Tanganyika, **182.**
Taeniorhynchus fuscopennatus, in huts in Kenya, **100** ; in Tanganyika, **182.**
Taeniorhynchus metallicus, in huts in Kenya, **100** ; in Tanganyika, **182.**
Taeniorhynchus uniformis, incidence of, in Kenya, **100, 106–108, 115–136** ; in Tanganyika, **182.**
Tanganyika Territory, list of Culicines of, **181–187** ; populations of *Aëdes* in, **187–193** ; *Podagrica puncticollis* on *Malva* in, **229.**
tatarica, Cyrtacanthacris.
taylori, Aëdes (*Diceromyia*).
tenuiventris, Ephialtes.
Tephrosia, food-plant of *Schistocerca gregaria* in India, **246.**
terebrans, Ephialtes.
Terminalia catappa (Indian Almond), mosquitos in tree-holes of, in Tanganyika, **188.**
testacea, Podagrica.
thalassius, Culex.
theileri, Culex.
theobromae, Podagrica.
Thisoicetrus persa, overwintering habits of, in India, **254.**
Thliptoceras octoguttalis, on coffee in Kenya, **80.**
Thrips, methods of sampling populations of, on coffee in Kenya, **147–148.**
tigripes, Culex (*Lutzia*).
Tirachola plagiata, experimental host of parasites of sugar-cane borers, **48, 52.**
Tribulus terrestris, food-plant of *Schistocerca gregaria* in India, **245, 246.**
Trichogramma evanescens, shipment of, into Mauritius from Ceylon against sugar-cane borers, **61–62.**
Trichogramma minutum, **61.**
Trichogramma semblidis, **61.**
trifoliatus, Culex.
Trigonella, food-plant of *Schistocerca gregaria* in India, **246.**
tristis, Anasa.
tritaeniorhynchus, Culex.
truncata, Phragmatiphila.
turneri, Podagrica.

U.

Uganda, Eumolpid on bean in, **31** ; new Halticids from, **231, 233** ; food-plants of *Podagrica* spp. in, **229.**
unifasciata, Podagrica.
uniformis, Podagrica ; *Taeniorhynchus* (*Mansonioides*).
univittatus, Culex.
Uranotaenia, emended key to larvae of, in Ethiopian Region, **177.**
Uranotaenia balfouri, in Tanganyika, **181.**
Uranotaenia fusca, in Tanganyika, **181.**
Uranotaenia mashonaensis, in Tanganyika, **181.**

V.

vanderwulpi, Cadurcia.
vansomereni, Culex.
varians, Pagria.
venosatus, Proceras (*Diatraea*).
versicauda, Cadurcia.
Vetiveria zizanioides, food-plant of, *Proceras venosatus*, **44.**
Viburnum opulus, tests with *Aphis rumicis* and, **17, 18** ; winter food-plant of *A. fabae*, **161.**
Vicia faba, tests with *Aphis rumicis* and, **17, 18** ; summer food-plant of *A. fabae*, **161.**

Vigna (Cowpea), Eumolpids on, **31.**
vignaphila, Pagria.
viridiaenea, Pagria.
viridipennis, Podagrica.
vittatus, Aëdes (Stegomyia).
vitticollis, Sibinia.
vuteria, Sesamia.

W.

watti, Culex.
weisei, Podagrica.
Wiesadula rostrata, Halticid on, in S. Nigeria, **229.**

X.

Xanthopimpla stemmator, morphology and bionomics of, **46–49** ; introduced into Mauritius from Ceylon against sugar-cane borers, **47, 55–57.**
xanthopus, Pagria (Nodostoma).

Z.

Zea mays (see Maize).
zetterstedti, Cadurcia.
ziemanni, Anopheles coustani.
zonellus, Chilo.

INDEX TO NAMES OF PERSONS.

Adler, S., **35.**
Afzal Husain, M., **259.**
Ahmad, Taskhir, **259.**
Arumugam, K. S., **64.**

Bartley, W. C., **267.**
Batra, R. N., **247.**
Beckley, V. A., **147.**
Bedford, H. W., **1, 2, 3.**
Bengtssen, R., **159.**
Bergold, G., **150, 159.**
Bevins, W., **232.**
Bodkin, G. E., **64.**
Brown, P., **267.**
Bryant, G. E., **31, 229.**
Butovitsch, V., **159.**
Buxton, P. A., **141, 239, 280.**

Cameron, M., **1.**
Cameron, W. P. L., **1, 2, 3.**
Conde, O., **150, 159.**
Cowland, J. W., **2, 3, 229.**
Cushman, R. A., **172.**

David, W. A. L., **195, 235.**
De Meillon, B., **193.**

Emden, F. I. van, **223.**

Fox, C. F., **88.**
Froggatt, J. L., **32.**

Garnham, P. C. C., **141.**
Gedye, A. F. J., **231.**
Gillett, J. D., **27.**
Gowdey, C. C., **233.**

Haddow, A. J., **91.**
Hancock, G. L. R., **229.**
Hargreaves, E., **229.**
Hargreaves, H., **229, 233.**
Harper, J. O., **99, 141.**
Harper, S. H., **280.**
Harris, W. V., **181.**
Hassan, A., **3.**
Heikinheimo, O., **159.**
Henry, G. M., **64.**
Hinton, H. E., **21.**
Hopkins, G. H. E., **175, 193.**
Hopkins, J. C., **229.**
Hurst, H., **217.**
Husain, M. Afzal, **259.**
Hutson, J. C., **64.**

Imms, A. D., **19.**

Jackson, T., **233.**
Jardine, N. K., **64.**
Jepson, W. F., **64.**
Joachim, J. W. R., **64.**
Johannessen, E., **159.**
Johnson, C. G., **267.**
Johnston, H. B., **1, 2.**
Jones, F. G. W., **19, 169.**
Jones, H. N., **88.**
Jones, M. G., **5, 161.**

Kangas, E., **159.**
Karandikar, K. R., **243.**
King, C. B. R., **64.**
King, H. H., **2, 3.**

Lamborn, W. A., **229.**
Leeson, H. S., **35.**
LePelley, R. H., **71, 147, 223, 224.**
Lewis, D. J., **227.**
Lloyd, H. M., **193.**

McArthur, **233.**
Macdonald, E. C. C., **175.**
Macfie, J. W. S., **229.**
Makkawi, A. M., **3.**
Malaise, R., **149** (*note*).
Marshall, Sir. G. A. K., **1, 229, 234.**
Martin, J. T., **217, 280.**
Mason, C., **229.**
Mason, E. W., **44.**
Meillon, B. De, **193.**
Mellanby, K., **267.**
Michelmore, A. P. G., **2, 3.**
Muir, F., **34.**
Munro, H. K., **229.**
Munro, J. W., **21.**

Nattrass, R. M., **88.**
Neave, S. A., **233.**

Paterson, A. R., **141.**
Patterson, W. H., **229.**
Perkins, J. F., **171.**
Petch, T., **45.**
Pettet, A. J., **280.**
Pohl, W., **202.**
Politzer, W., **147.**
Pratt, D. D., **280.**

Ramchandra Rao, Y., **241.**
Richards, O. W., **21.**
Riley, N. D., **21.**
Ritchie, A. H., **229.**
Robinson, G. G., **273.**
Ruttledge, W., **229.**

Saliternik, Z., **221.**
Schmiedeknecht, O., **173.**
Sellers, W. F., **149.**
Shepperdson, A., **212** (*note*).
Simmonds, F. J., **171, 173.**
Someren, E. C. C. van, **175, 178, 193.**
Someren, G. R. C. van, **175, 231.**
Symes, C. B., **141.**

Tams, W. H. T., **21, 39** (*note*), **67, 232.**
Taskhir Ahmad, **259.**
Tattersfield, F., **218.**
Theodor, O., **35.**
Thompson, W. R., **52.**
Thomsen, M., **159.**
Thorpe, W. H., **169.**
Trägårdh, I., **159.**
Turner, A., **234.**
Turner, H. J. A., **231.**
Turner, R. E., **33.**

Uvarov, B. P., **241.**

van Emden, F. I., **223.**
van Someren, E. C. C., **175, 178, 193.**
van Someren, G. R. C., **175, 231.**
Vinson, J., **39.**

Wall, W., **218.**
Westman, J., **159.**
Wigglesworth, V. B., **202, 205, 239.**
Wilkinson, H., **231.**
Wilson, D. B., **115.**